AN ECONOMIC ANALYSIS OF THE BENEFITS AND COSTS OF THE CLEAN AIR ACT 1970 TO 1990

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of Results and Findings

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Executive Summary

The Clean Air Act and its subsequent amendments to 1990 were legislative initiatives designed to improve air quality and reduce the adverse consequences of air pollution. As a result, they imposed costs on producers and consumers as economic activities were brought into compliance with their statutory requirements. However, they also secured improvements in air quality by reducing the lead content in gasoline and pollutant emissions to the ambient atmosphere. In turn, these lead to improvements in the health and well-being of the population. The analyses covered in this report examine the consequences of these costs and benefits for overall economic performance and welfare. They are based on the application of a multi-sector, inter-temporal general equilibrium model of the U.S. economy. The approach taken is to develop a counter-factual view of how the economy might have evolved had there been no Clean Air Act.

The costs arising from the Clean Air Act, analyzed absent of the economic benefits from improvements in environmental quality, adversely affect economic performance. Real consumption and income ultimately are one percent lower due to its enactment. The causes of these effects are the policy's impact on capital formation and its impact on productivity at the industry level. For compliance, a portion of each new dollar of invested capital now is devoted to pollution abatement. In addition, capital and other resources are diverted from their previously productive uses to the retrofitting of existing capital and to the operation and maintenance of both new and existing capital, the latter being the productivity effect.

The benefits arising from the Clean Air Act, analyzed absent of cost considerations, enhance economic performance. Real consumption and income ultimately are almost three percent higher in its presence. Here, the cause is principally the policy's favorable impact on reducing the illnesses, intellectual costs and pre-mature deaths associated with air pollution. As these directly affect the availability of labor inputs to production and the availability of consumers as purchasers, the presence of the clean air act implies a larger economy from both the perspectives of supply and demand.

In combining these effects, the Clean Air Act provides the economy undeniable net economic benefits. Ultimately, real consumption and income are two percent higher than they would be without its enactment. Initially, there are economic losses as the private costs of compliance exceed the benefits of the avoided damages to life and health. However, there soon are annual net benefits as the consequences of avoided deaths and work-loss days more than compensate the long-run cost implications of the Act's provisions. By the mid-1990s, there are cumulative net benefits that continue to grow as the time horizon is extended.

Over the simulation period and beyond, these net benefits accumulate to sizeable amounts. From a welfare perspective (computed as *present value equivalent variations and willingness-to-pay*), there are cumulative net gains of $(1990) 26.2 trillion. The benefits of the CAA far outweigh its costs. Mortality benefits accumulate to $(1990) 21.1 trillion while the benefits associated with morbidity and productivity improvements total $(1990) 6.8 trillion. Compliance with the provisions of the CAA entails a welfare loss of $(1990) 1.7 trillion in terms of the market values of goods, services and leisure foregone.

The Clean Air Act also has important implications for the structure of the U.S. economy and its patterns of energy use. The sectors most affected by it are petroleum refining, motor vehicles production and electric utilities. Lesser impacts are observed for mining, chemicals, primary metals and gas utilities. In the presence of the Clean Air Act, the economy is much less petroleum-, auto- and electric-intensive than it otherwise would be and much more coal- and gas-intensive than it otherwise would be. The energy- and pollution-intensities of the economy are significantly reduced through the Act's provisions. However, there is a major irony arising from its enactment. Because the economy is larger in its presence, the levels of energy use and (carbon) emissions are ultimately about 0.5 percent higher than they would be in absence of the Act. Moreover, the carbon-intensity of fossil fuel use is higher under the Act due to the reduced petroleum- and increased coal-intensity of the nation's energy-consuming capital stock.

1. Introduction

This analysis examines the benefits and costs of the 1970 Clean Air Act (CAA) and its 1977 Amendments in an effort to determine an overall value of the policy's merits. Upon its passage, the great bulk of the nation's energy-consuming capital stock was misaligned with the objectives of improved air quality through reductions in lead content and emissions of criteria pollutants. The enactment of the CAA imposed clear and tangible costs on producers and consumers as the nation was forced to bring new and existing capital into compliance with the Act's provisions. Its enactment also gave rise, perhaps less visible and immediate, to improvements in the health and welfare of the U.S. citizenry and to benefits to the nation's ecological and economic systems. As part of the 1990 CAA Amendments, Congress required the U.S. Environmental Protection Agency (EPA) to conduct "periodic, scientifically reviewed studies to assess the benefits and costs of the Clean Air Act (U.S. EPA, 1997)."

In 1993, Dale Jorgenson Associates reported on their detailed analyses of the economic costs associated with compliance to the 1970 and 1977 act and amendments (Jorgenson, et. al., 1993). Using a multi-sector, dynamic general equilibrium model of the U.S. economy, it was determined that these enactments adversely affected economic performance. Real consumption and income ultimately would have been one percent higher in their absence. The impacts on producers were not uniform. Sectors like motor vehicles, petroleum refining and electric utilities were most affected. Distributionally, for an infinitely-lived family of size four headed by a white male, age 35-44, living in the urban Northeast, the willingness to pay for not having to absorb the costs of compliance was estimated to be almost \$(1990) 8,300 per household in present value terms or 0.8 percent of lifetime consumption. This translates to an annual tax of \$(1990) 230 per household in perpetuity. Aggregating across all households, the estimated willingness to pay for society as a whole was in the range of \$(1990) 500 to 700 billion in terms of lifetime consumption. Finally, the compliance costs were found to be regressive to income and expenditure (Jorgenson, et. al., 1993). Two-thirds of these damages arose from the costs associated with stationary sources of air pollution; the remaining one-third was related to the costs arising from mobile source initiatives.

The analysis reported herein extends this earlier work. In particular, the aforementioned model, absent of distributional considerations, is used to evaluate the estimated benefit stream arising from the 1970 and 1977 act and amendments and to perform a net benefit analysis incorporating the costs previously assessed. As before, the costs and benefits of the CAA were analyzed independently. In turn, these were quantified in a manner that allows their introduction into the modeling framework in appropriate ways so as to isolate and measure the policy's direct and indirect consequences. As the model was estimated over an interval that encompasses the enactment period, the method of analysis is to observe how the economy might have evolved had there been no Clean Air Act and to provide measures of the consequences attendant to compliance with it.

The remainder of this report is organized as follows. Section 2 provides a brief description of the model employed in this analysis. Sections 3 and 4 discuss the costs and benefits of the CAA, respectively. They also cover the manner in which the costs and benefits were introduced into the model. Sections 5, 6 and 7 present the simulation results. Section 5 focuses on the macroeconomic impacts as measured by real Gross Domestic Product (GDP), consumption and investment. The primary inputs of capital and labor also are discussed, as are the welfare implications in terms of foregone consumption. Section 6 addresses the energy and environmental impacts of the CAA at the aggregate level. Energy changes are examined in terms of total fossil fuel use while environmental effects are evaluated in terms of the resulting carbon emissions. Finally, Section 7 reports on the industry details as reflected in the prices paid by producers and consumers and changes in the composition of domestic output.

2. Methodology

The results of this analysis are based on simulations conducted with the Intertemporal General Equilibrium Model or IGEM developed by Ho, Jorgenson and Wilcoxen. This is a multi-sector, multi-period model of the U.S. economy. It is one of a class of models called computable general equilibrium (CGE) models because it solves for the market-clearing prices and quantities of each sector and market in each time period. The parameters (or coefficients) of the equations in IGEM are estimated statistically from historical data spanning 50 years. The model consists of 35 producing sectors, the household or consumer sector, a business investment sector, the federal, state and local governments sector, and a foreign sector. Formal descriptions of the methodology and its components are numerous and appear in Ho (1989), Jorgenson and Slesnick (1985 and 1987), Jorgenson, *et al.* (1992) and Wilcoxen (1988).

In the IGEM model, production is disaggregated into 35 separate commodities produced by one or more of 35 industries. The industries (see Table 2.1) generally match two-digit sectors in the Standard Industrial Classification (SIC). Each industry or producing sector produces one primary product and may produce one or more additional goods or services. Each producing sector is modeled by a set of equations that fully represent possible substitutions among its inputs or factors—i.e., capital, labor, non-competing imports, and the 35 commodities.

Within each producing sector, changes in input demand (i.e., substitutions) occur because relative prices change, encouraging more or less use of that input. In addition, historical data invariably reveal trends (or biases) in input use that are independent of input prices. This means there is either increasing or decreasing input usage over time, even after accounting for the changes arising from relative price incentives. For example, historical data may indicate that particular industries are increasingly labor-saving, energy-saving, or capital-using over time, independent of relative prices. The equations used to model production in IGEM account for both price- and trend-related substitution effects. Industry-level productivity growth also is part of the specification for each of the 35 producing sectors estimated statistically from observed changes in input prices and observed technological trends.

These equations, along with others in the model, are organized in an inter-industry framework in which the demands for and supplies of each commodity, as well as those of capital and labor, must balance in terms of both quantity and value (i.e., price times quantity). The organization of annual "use" and "make" tables is illustrated in Figure 2.1. These are "spreadsheets" at the industry and commodity level of detail. The "cells" in each use table depict commodity purchases (the rows) by each industry and final demand (the columns). The "cells" in each make table show the commodities produced by each industry. Figure 2.1 also shows the inputs of capital and labor into each producing and consuming sector.

Figure 2.2 depicts production and supply. Inputs of the 35 commodities plus capital, labor and non-competing imports are combined to produce domestic industrial outputs. In turn, these outputs are mapped into domestic commodity outputs through the use and make tables. Combining the domestic commodities with competitive foreign imports gives rise to the available supplies, which are purchased as intermediate inputs or finished goods (final demand).

The model is solved iteratively until the prices of all commodities and inputs are such that demand equals supply in all product and factor (input) markets. Model solutions depict, among other things, all prices and quantities, the complete structure of inputs to production, and industry-level rates of technological change. As a result, economy-wide changes in energy or capital intensity, for example, are calculated by adding up industry-level details. There are none of the so-called autonomous "economy-wide" energy efficiency improvements (i.e., assumed declines in the amount of energy required to produce a given level of output over time, with labor and capital unchanged), except those arising from the assumed continuation of independent technological trends. (Experimentation has shown that these technological trends in the use of such factors as energy or capital comprise around twenty percent of the overall adjustment to new energy conditions, with substitution or relative price effects explaining the remaining eighty percent [Jorgenson, *et.al.*, 1993]).

Household consumption by commodity is the result of a three-stage, multi-period decision process (see Figure 2.3) involving price and demand equations like those of the producing sectors. First, households decide their levels of "full consumption" over time. Full consumption, comprising goods, services *and* leisure, is the amount of financial wealth "consumed" in each period and is dependent on relative prices, current and future, and on the time path of interest rates (both of which are known to households with perfect foresight). Financial wealth is the (present) value of household capital wealth (private, government and foreign) and the household time endowment.

The household time endowment is a population-based, monetary estimate of the amount of time available to the working-age population (those 14 through 74 years old) for work and leisure. It assumes that there are 14 hours per day of discretionary time for work and leisure with appropriate allowances for weekends, holidays and hours spent in school. The time endowment is evaluated at the prevailing wage or after-tax rate of labor compensation, including benefits and is adjusted for quality (i.e., educational attainment and experience). Leisure is defined as the uncompensated use of time (i.e., that portion of the 14 hours that people use for activities other than paid work). (This is not the ideal measure of leisure in that it includes commuting, illness and many other uses of time that would not be considered "leisure" in the usual sense of the word. However, construction of a pure measure of leisure is probably beyond available data.)

Once households decide each period's full consumption, they then decide the split between the consumption of goods and services and the demand for leisure. This decision is based on the price of consumption relative to the wage rate (the opportunity cost, or price of leisure). When households decide their leisure demand, they simultaneously determine their labor supply and, so too, their labor income. Finally, households choose the allocation of total consumption among capital, labor, and the various categories of goods and services. Like production, these stages of household behavior are estimated statistically from historical data, and the equations capture both price- and income-driven changes in observed spending patterns.

In the model, capital accumulation is the outcome of a series of decisions over time by households and firms. Households and businesses determine the amount of saving available in each period as the difference between their income and expenditures. Households and firms invest until the returns on additional investment are no longer greater than the cost of new capital goods. Capital is assumed to be perfectly mobile across households and corporate and non-corporate enterprises; in other words, capital flows to where it is needed. (In the real world, there are, most likely, severe constraints on the near-term mobility of capital.) Investment is structured according to a statistically estimated model allowing substitutions among different types of capital goods. The total supply of capital at any time is fixed by the accumulated investment in these capital goods.

Government purchases are calculated to balance the available government revenues and a predetermined budget deficit. Government revenues arise by applying tax rates, both historical and projected, to the levels of income and wealth generated by the model. The composition of government spending – for example, spending on automobiles, computers, highways, schools, and employees – is fixed by assumption.

Finally, the international exchange rate of the dollar against other currencies adjusts to bring net exports (exports less imports) into line with a predetermined trade balance in goods and services. This means that net foreign saving is insensitive to changes in U.S. prices and interest rates. Imports are considered imperfect substitutes for similar domestic commodities and compete on price, which in turn depends on the value of the relevant foreign currency. Export demands depend on assumed foreign incomes and the foreign prices of U.S. exports, which, in turn, are determined by domestic prices and the exchange rate.

The assumptions regarding the budget and trade deficits drive important aspects of the process of capital formation. In combination, they imply that no "crowding-out" of private investment occurs as a result of changes in investment by either the government or foreign sectors. Holding the budget and trade deficits constant across simulations means that neither governments nor foreigners influence the level of investment spending beyond what is assumed for the base case. As a result, investment changes from one simulation to another depend entirely on changes in saving by households and businesses.

On the supply side, overall economic growth in IGEM, as in the real world, arises from three sources. These are productivity, accumulated capital, and the availability of labor. The model itself determines two of these – productivity and capital. Productivity depends on emerging trends in relative prices combined with the continuation of observed technological trends. Capital accumulation occurs as a result of the saving and investment behavior of producers and consumers. Labor supply is determined as households allocate their discretionary time between work and leisure. All of these, therefore, are products of the model. U.S. population growth by age, race, sex, and educational attainment is projected through 2050 using demographic assumptions consistent with U.S. Social Security Administration forecasts; after 2050, population is held constant. As indicated above, the population projection is used to calculate a projection of the economy's "time endowment" in dollar terms by applying historical wage patterns to estimates of the working-age population. Since the model largely determines productivity and capital accumulation, these population projections effectively determine the size of the economy in the distant future.

Models are necessarily an abstraction of the environment they portray, and IGEM is no exception. In characterizing the results from this methodology, three features merit consideration. Two of these are assumptions, while the third derives from the source of the model's parameters. First, as indicated above, consumers and producers in IGEM are assumed to have perfect foresight and are able to react today to expected future price changes. This means that they behave according to so-called "rational expectations." There are no surprises in the form of price shocks. Since producers and consumers immediately plan for and adopt new technologies, there are no losses associated with equipment becoming prematurely obsolete when technology or relative prices change repeatedly. Second, capital income and the corresponding stock of capital goods and services are assumed to be perfectly mobile among industries, households, and governments. This implies that capital can migrate from sector to sector with little or no adjustment cost. Moreover, there are no capacity shortages or supply-demand imbalances associated with this migration. Instead, equipment is effortlessly transformed into some other use.

Finally, the model parameters in IGEM are based on 50 years of historical data. Much has changed in these 50 years and these parameters reflect and embody these changes. Hence, model adjustments and reactions to changing economic conditions are based on observed long-term trends and any short-run constraints on or lags in adjustment behavior that are part of this history.

Taken together, these features imply that IGEM is more likely than other models are to produce "best" case outcomes (least losses or greatest gains) when confronted with significant economic changes. Households and businesses are fully aware of these changes through perfect foresight, substitution possibilities are long-run in nature and occur quickly and easily, and capital readily migrates and mutates to new uses. Conversely, myopia, inflexibility in production and consumption, and low capital stock turnover are conditions that lead to "worst" case outcomes (greatest losses or least gains). In comparing model estimates of the economy's response to environmental policies, those from IGEM will appear less damaging (or, more beneficial) than those from models in which there are more rigidities or higher adjustment costs.

Table 2.1: Definitions of Industries-Commodities

Number	*Description*
1	Agriculture, forestry and fisheries
2	Metal mining
3	Coal Mining
4	Crude petroleum and natural gas extraction
5	Non-metallic mineral mining
6	Construction
7	Food and kindred products
8	Tobacco manufactures
9	Textile mill products
10	Apparel and other textile products
11	Lumber and wood products
12	Furniture and fixtures
13	Paper and allied products
14	Printing and publishing
15	Chemicals and allied products
16	Petroleum refining
17	Rubber and plastic products
18	Leather and leather products
19	Stone, clay and glass products
20	Primary metals
21	Fabricated metal products
22	Non-electrical machinery
23	Electrical machinery
24	Motor vehicles
25	Other transportation equipment
26	Instruments
27	Miscellaneous manufacturing
28	Transportation and warehousing
29	Communications
30	Electric utilities (services)
31	Gas utilities (services)
32	Wholesale and retail trade
33	Finance, insurance and real estate
34	Other personal and business services
35	Government enterprises

Figure 2.1: Organization of the Use and Make Tables

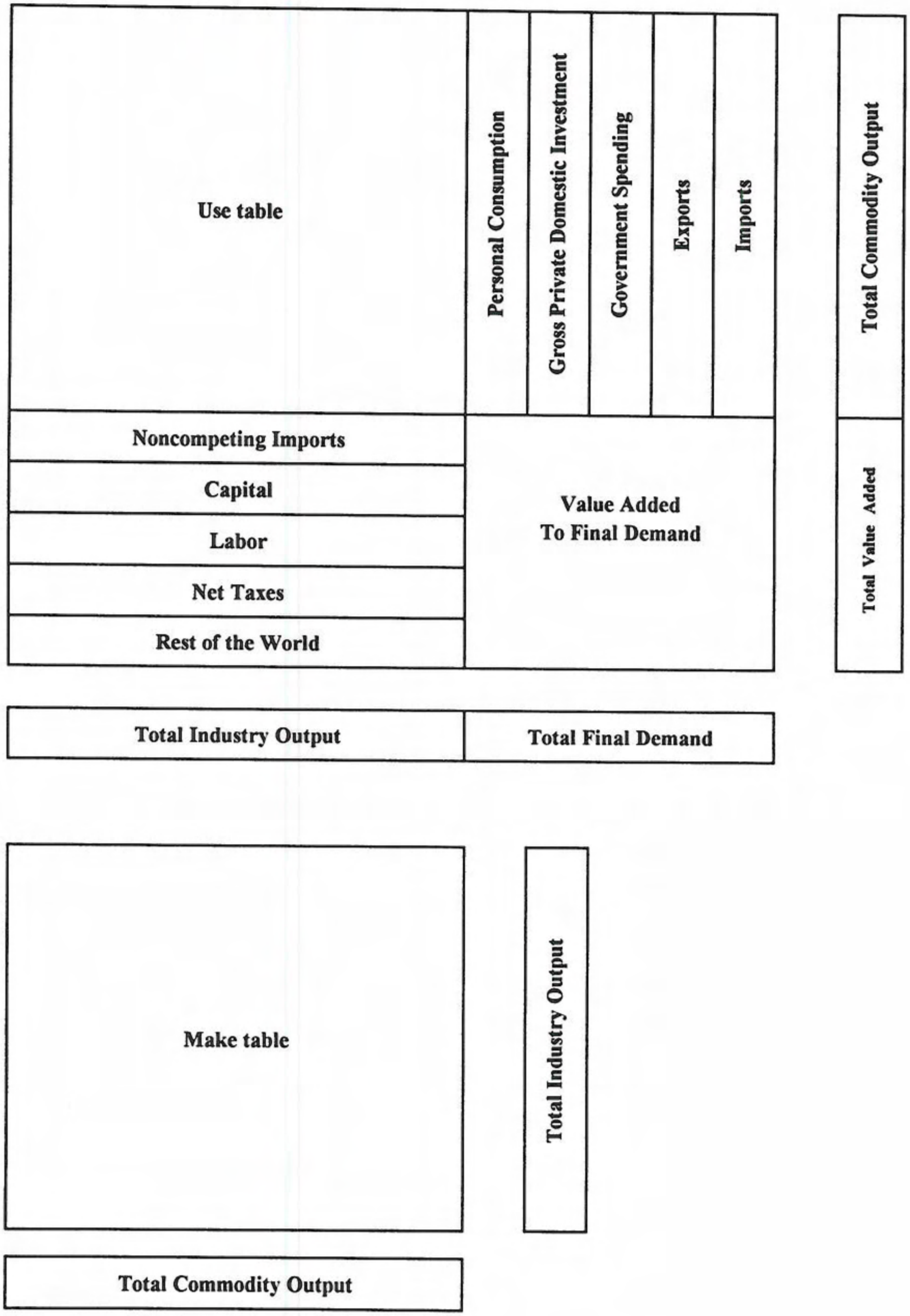


Figure 2.2: The Model Flows of Production and Commodity Supply

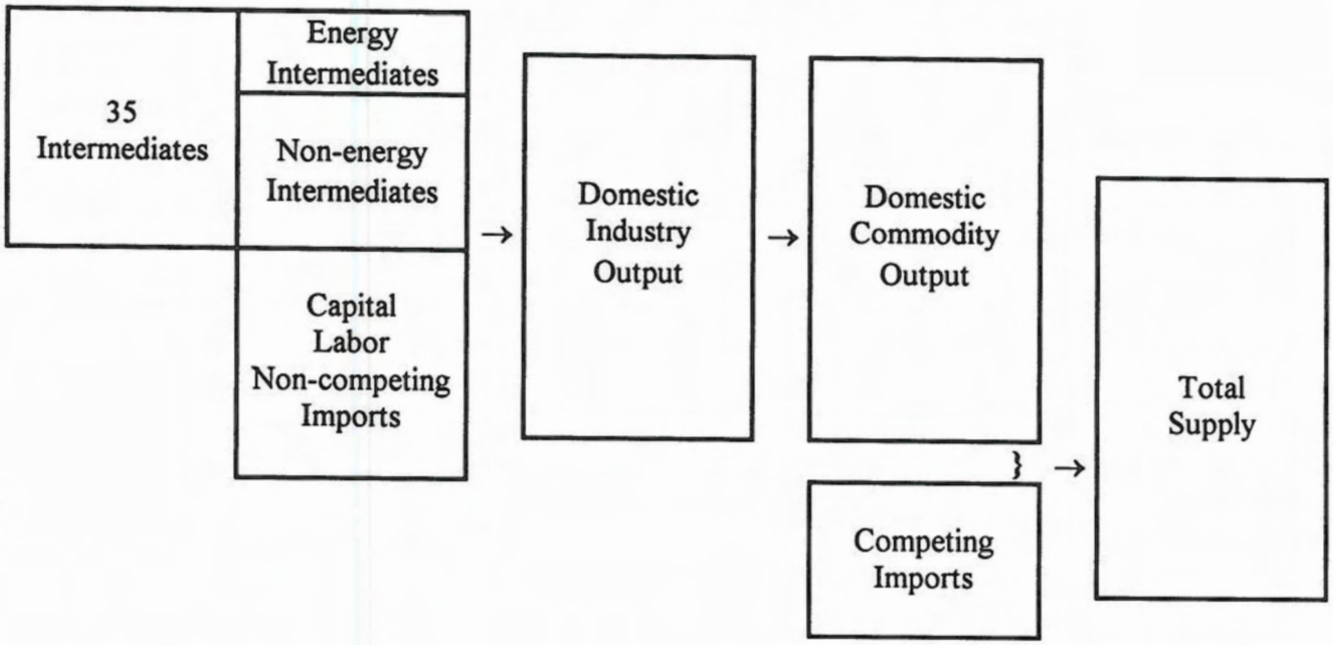
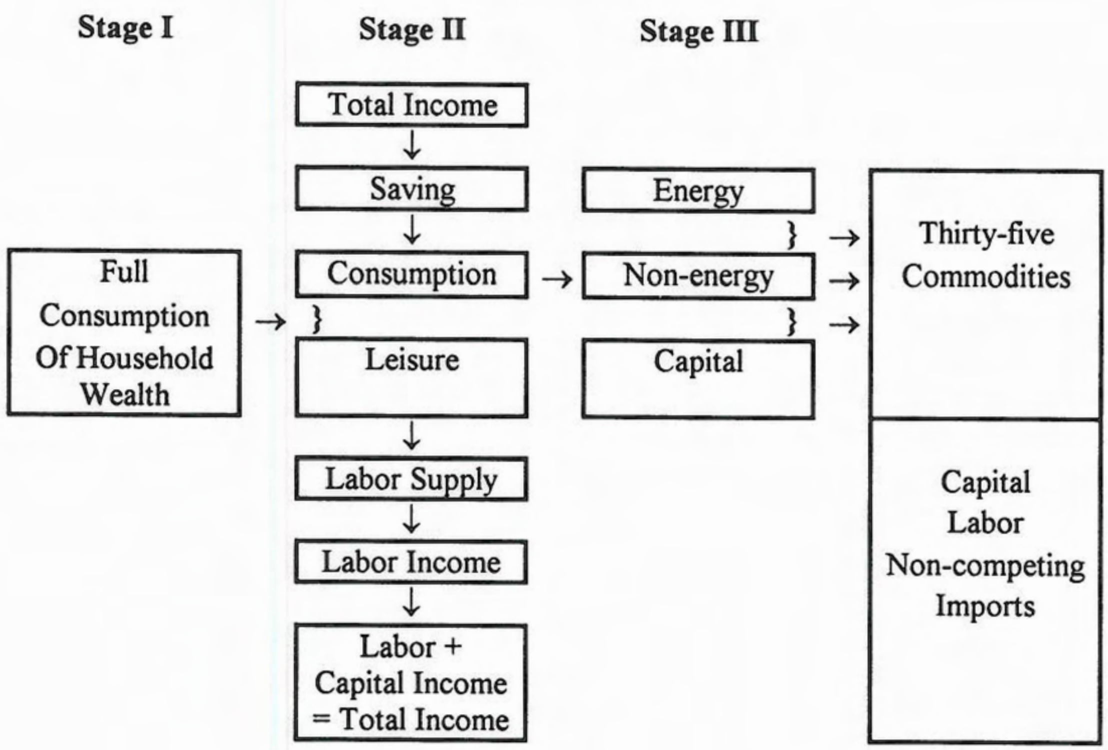


Figure 2.3: The Model Flows of Household Behavior



3. The Costs of Compliance

The CAA compliance costs included in this analysis cover capital and operating and maintenance (O&M) outlays for non-farm stationary sources. Recovered costs associated with pollution control in manufacturing are subtracted from O&M outlays. Capital, maintenance and fuel-related charges for mobile source air pollution control complete the compliance cost data. The fuel-related charges for mobile sources combine the fuel price and fuel economy penalties associated with lead-free gasoline. The compliance costs for government expenditures for pollution abatement, research and development, and regulation and monitoring are not included in these simulations as they have an almost negligible impact on the overall results. Private R&D outlays also are omitted from consideration since there is no basis for allocating them to specific industries or specific purchases. The sources of these data and the database of air pollution control expenditures developed for this analysis are discussed in Jorgenson, et. al. (1993) and EPA (1997). A summary of the aggregate cost information appears below in Table 3.1.

Table 3.1: The Direct Costs Of Compliance
Compliance Costs in Millions

	Stationary Sources		Recovered	Mobile Sources			TOTAL
	Capital	O&M	Costs	Capital	O&M&Fuel	Other	COSTS
1972	2,235						
1973	3,050	1,436	199	276	1,765	836	7,164
1974	3,432	1,895	296	242	2,351	866	8,490
1975	4,016	2,240	389	1,570	2,282	897	10,616
1976	3,954	2,665	496	1,961	2,060	1,009	11,153
1977	4,008	3,223	557	2,248	1,786	1,174	11,882
1978	4,182	3,724	617	2,513	908	1,325	12,035
1979	4,898	4,605	750	2,941	1,229	1,448	14,371
1980	5,449	5,568	862	2,949	1,790	1,410	16,304
1981	5,586	6,123	997	3,534	1,389	1,348	16,983
1982	5,594	5,815	857	3,551	555	1,299	15,957
1983	4,577	6,292	822	4,331	-155	1,297	15,520
1984	4,698	6,837	870	5,679	-326	1,314	17,332
1985	4,469	7,186	768	6,387	337	1,488	19,099
1986	4,402	7,256	867	6,886	-1,394	1,548	17,831
1987	4,456	7,599	987	6,851	-1,302	1,594	18,211
1988	4,510	7,474	1,107	7,206	-1,575	1,670	18,178
1989	4,995	7,916	1,122	7,053	-1,636	1,788	18,994
1990	4,395	8,842	1,256	7,312	-1,816	1,542	19,019

Sources: Appendix A, Jorgenson, et. al. (1993) and Table A-8, EPA (1997). Costs prior to 1973 were determined by linear interpolation, 1970 being zero.

Annual CAA compliance costs average almost $15.0 billion over the period 1973-1990. Of this, stationary source capital and net operating expenditures average $4.5 billion and $4.6 billion, respectively. The total compliance costs for mobile sources account for over thirty percent of all compliance costs or $4.5 billion of the average total expenditure. Government outlays and private R&D expenditures average $1.3 billion, 1973-1990, and are not included in these simulations. Government outlays are excluded because they are very small in magnitude and their effects are negligible. Private R&D expenditures are excluded because there is no basis for allocating them to specific industries or identifying the benefits arising from them. Thus, the CAA costs omitted from consideration are about 15% of the costs for all stationary sources and about 9% of total compliance costs.

Two points regarding the compliance cost series merit discussion. First, all non-mobile source costs were based on U.S. Department of Commerce, Bureau of Economic Analysis (BEA) surveys and analyses through the early 1990's. In the mid-1990's, BEA published "final" adjusted data on these cost series. For comparability to earlier analytical efforts, these final series were not considered in this assessment. Second, the cost series above represent all air pollution abatement expenditures, including those that would have occurred even in the absence of the CAA. However, the benefit estimates reflect only the changes in air quality due to the CAA, thus biasing any benefit-cost conclusions. It is known that industry incurred expenses for air pollution control prior to 1970 and, presumably, would have continued to do so without the Act's impetus. Unfortunately, there is no basis for isolating the costs only attributable to the Clean Air Act. Accordingly, benefit-cost attributions remain so qualified.

The costs included for analysis average over four tenths of one percent of total domestic output over the period 1973-1990. However, they are front-loaded, comprising over one-half of one percent of total output in the early years and falling to three tenths of one percent by 1990. In terms of disposable household income, the costs average just under six tenths of one percent from 1973-1990.

As environmental regulations are imposed, investment funds are allocated to pollution control activities. If the supply of savings is fixed and if expenditures on pollution control confer no benefits beyond compliance with the law, then there is a loss in ordinary, productive capital accumulation. This occurs for two reasons. First, there is a permanent loss due to the fact that each new unit of capital has a pollution control component embodied in it. Second, there is a transitory loss due to the need to bring existing capital into compliance.

To eliminate the capital portion of the CAA compliance costs, the percentage of air pollution abatement investment in total investment first was determined. This then was split in order to separate the windfall loss of having to install abatement equipment on old capital from the permanent effect of the control equipment required for each new unit of capital. It was assumed that the 1990 share of pollution control investment in total investment was a reasonable measure of the permanent effect. This meant that the outfitting of old capital was largely achieved by 1990. This 1990 percentage then was deducted from the overall share of abatement investment in total investment to determine the windfall loss accruing to the owners of existing sources.

The permanent effect was introduced into IGEM as a reduction in the price of investment goods. This follows from the idea that under the CAA purchasers of capital goods had to buy a certain amount of abatement capital in each unit of new productive capital, thereby increasing the price of new capital goods.

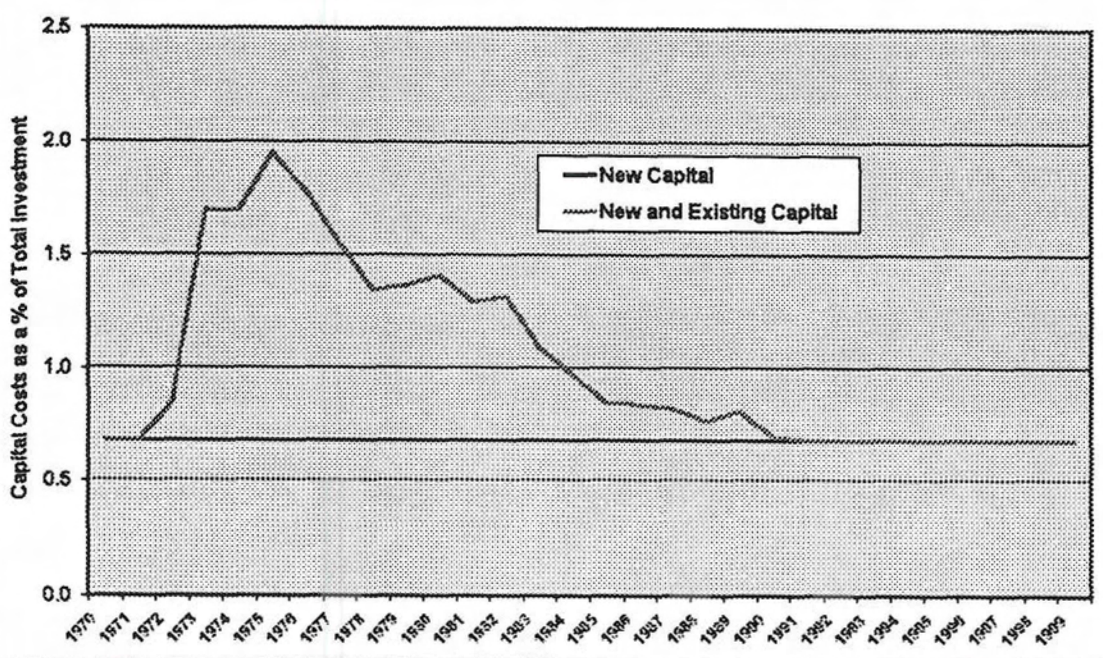
The windfall or transitory effect was applied to the capital accumulation process. In each of the transitory years, 1973-1989, the outlays on abatement equipment for existing sources were returned to increase the ordinary capital formation that occurred that year.

These percentages for these effects are shown below in Table 3.2 and Figure 3.1. In 1975, for example, 1.95 percent of total investment was devoted to pollution control equipment; of this 0.70 percent related to new capital (the permanent effect) while the remaining 1.25 percent brought existing capital into compliance (the transitory effect).

Table 3.2:
Pollution Control Capital Expenditures for Stationary Sources as a Percent of Total Investment

Year	Pollution Control Component for New Capital in Percent	Pollution Control Component for Existing Capital in Percent
1973	0.70	1.00
1974	0.70	1.00
1975	0.70	1.25
1976	0.70	1.09
1977	0.70	0.86
1978	0.70	0.65
1979	0.70	0.67
1980	0.70	0.71
1981	0.70	0.59
1982	0.70	0.62
1983	0.70	0.39
1984	0.70	0.27
1985	0.70	0.15
1986	0.70	0.14
1987	0.70	0.12
1988	0.70	0.07
1989	0.70	0.11
1990	0.70	0.00

Figure 3.1: Pollution Control Capital Expenditures
Stationary Sources, New and Existing Capital



The operation and maintenance of air pollution control devices increases the factor input requirements per unit of output for each affected producing sector. The first step in eliminating the operating portion of the CAA compliance costs was to compute the share of these in the total costs of each industry. For the manufacturing sectors, these costs were net of any recovered costs associated with the operation of pollution control equipment. Reducing the unit cost functions in the production model by these proportions then simulated removal of these costs. The (net) additional resources required to operate and maintain this equipment were released in a Hicks-neutral fashion; that is, for a given amount of output at fixed factor prices, each industry's input demands declined in the same proportion.

Unlike the stationary source abatement expenditures, the mobile source compliance costs are borne by the users rather than the producers of selected products. The CAA altered the purchase prices of motor vehicles (sector 24) and other transportation equipment (sector 25), refined petroleum products (sector 16) and vehicle repair and maintenance (sector 34). Removal of these costs is accomplished in a manner identical to the removal of the stationary source operating costs. First, in each category, the abatement cost share of total expenditure was determined. For motor vehicles and refined petroleum, total expenditures included purchases from domestic and foreign sources. Also, the refined petroleum effect includes a fuel price penalty that is always a cost in these data and a fuel economy penalty that initially is a cost but ultimately becomes a benefit. Finally, vehicle maintenance (part of sector 34, personal and business services) benefits from the Clean Air Act in that automobiles are less costly to service; thus, removal of the CAA harms this sector whereas all other aforementioned sectors benefit.

The unit cost functions for the affected sectors along with the relevant import prices then were additionally altered in proportion to the mobile source cost shares.

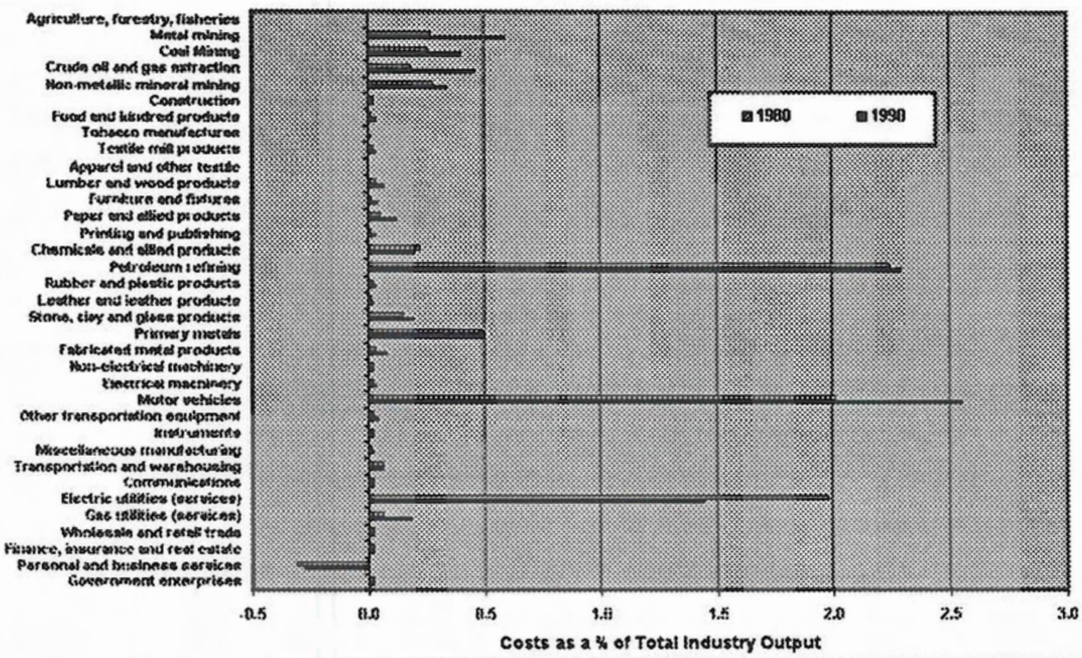
A summary of the net operating and maintenance and mobile compliance cost information appears below in Table 3.3 and Figure 3.2.

Table 3.3:
Pollution Control Expenditures
as a Percent of the Value of Industry Output

Sector	Industry Name	1980	1990
1	Agriculture, forestry, fisheries	0.00	0.00
2	Metal mining	0.27	0.59
3	Coal Mining	0.26	0.40
4	Crude oil and gas extraction	0.18	0.46
5	Non-metallic mineral mining	0.28	0.34
6	Construction	0.02	0.02
7	Food and kindred products	0.01	0.03
8	Tobacco manufactures	0.00	0.01
9	Textile mill products	0.02	0.03
10	Apparel and other textile products	0.00	0.00
11	Lumber and wood products	0.03	0.07
12	Furniture and fixtures	0.01	0.04
13	Paper and allied products	0.05	0.12
14	Printing and publishing	0.01	0.03
15	Chemicals and allied products	0.22	0.20
16	Petroleum refining	2.24	2.29
17	Rubber and plastic products	0.02	0.03
18	Leather and leather products	0.01	0.02
19	Stone, clay and glass products	0.15	0.19
20	Primary metals	0.49	0.50
21	Fabricated metal products	0.03	0.08
22	Non-electrical machinery	0.02	0.02
23	Electrical machinery	0.02	0.03
24	Motor vehicles	2.01	2.55
25	Other transportation equipment	0.02	0.04
26	Instruments	0.02	0.02
27	Miscellaneous manufacturing	0.01	0.02
28	Transportation and warehousing	0.06	0.06
29	Communications	0.02	0.02
30	Electric utilities (services)	1.98	1.44
31	Gas utilities (services)	0.06	0.18
32	Wholesale and retail trade	0.02	0.02
33	Finance, insurance and real estate	0.02	0.02
34	Personal and business services	-0.31	-0.28
35	Government enterprises	0.02	0.02

Figure 3.2 Industry Compliance Costs

Stationary Source O&M Costs (Net of Recovered Costs) and All Mobile Source Costs



4. The Benefits from Compliance

The Clean Air Act secured improvements in the general health and welfare of the population through reductions in lead concentrations and emissions of particulate matter (total suspended particulates), sulfur dioxide, nitrogen oxides, volatile organic compounds and carbon monoxide. These benefits are organized under three broad categories: mortality effects, morbidity effects, and expenditure effects. Mortality effects are associated with the pre-mature deaths of men, women and children as a consequence of exposures to lead and the other pollutants. Morbidity effects are associated with the restricted activity and workdays lost arising from illnesses related to these same exposures. The illnesses considered include chronic bronchitis and other respiratory ailments, heart disease and congestive heart failure, stroke and hypertension. Lost IQ points due to exposures to lead also are viewed as affecting the quality and quantity of available labor inputs. Expenditure effects are associated with household spending that arises in absence of the protections afforded by the Clean Air Act. These include physician and hospital admissions expenses, home maintenance expenditures related to soiling damages and compensatory outlays for needed education.

Appendix D of EPA's 1997 *The Benefits and Costs of the Clean Air Act, 1970 to 1990* formed the basis of the benefit measures considered here. This appendix collected and summarized the human health and welfare effects that were estimated for the criteria pollutants identified in the Clean Air Act. With these data as starting points, the staff at EPA's National Center for Environmental Economics interpolated the benefits for intervening years, 1970-1990, and provided "best estimate" extrapolations of the benefit streams to the year 2100, the terminal year of analysis. These extrapolations were necessary because, logically, the benefits of compliance, unlike the costs that are presumed to reach a steady state by 1990, continue to grow well into the future serving both current and future generations as they age and come into existence, respectively. The documentation and benefit estimates developed by EPA appear as Appendices A, B and C to this report.

Of interest in this assessment are the relative contributions of lead and non-lead pollutants in the mix of overall benefits. As it turns out, these vary by benefit category. For mortality effects, lead contributes but a small fraction of the overall damages, rising from 2.4 percent of avoided deaths in 1971 to a steady-state 10.0 percent by 1990. For the morbidity effects, lead is more important as its growing adverse consequences do not materialize until the early 1990's. From 1970 to 1993, activity days lost related to lead concentrations are in the range of 4.0 to 6.0 percent of all pollution-related days lost. Beginning in 1993, this percentage rises steadily to 13.0 percent by 2000, to 29.0 percent by 2010, to 41.0 percent by 2020 and to a steady state of around 57.0 percent by 2050. Lead is most significant as a percentage of avoided expenditures. Here, lead's share rises from 27.0 percent in 1971 to almost 59.0 percent by 1990. Lead's percentage of avoided expenditure hovers in the sixty percent range over the remainder of the simulation period.

Introducing EPA's benefit estimates into the IGEM methodology requires certain actuarial adjustments. These are shown in Table 4.1 below. In that persons both die and retire, there comes a point in time in which an avoided death or activity day lost no longer appears as a cumulative benefit because the individual in question has either died or is no longer working age. Accordingly, the EPA benefits were adjusted to account for normal deaths and aging. Mortality affects both the population (the number of household equivalent members or consumers) and the time endowment of labor in IGEM. The time endowment of labor comprises fourteen hours per day devoted to work and leisure for each member of the working-age population, ages 14 to 74. It is adjusted for hours spent in school and for quality related to educational attainment. It is expressed in dollars, reflecting the prevailing after-tax compensation received per unit of labor services provided to employers. For the population adjustment, it was assumed that persons no longer contribute avoided-death benefits past their middle- to late-eighties; thus, each age-cohort series in the EPA data was lagged an actuarially appropriate number of years to assure its removal from the benefit stream. The avoided deaths in any given year thus represent EPA's estimated cumulative avoided deaths to this date less any cumulative deaths to this date that would have occurred anyway. The mortality effects on labor's time endowment were determined similarly, the only differences being that persons over 75 were not considered part of the labor force (and, hence, were not considered avoided-death benefits) and that persons were assumed to retire by age 75 (and, hence, should no longer be counted as an avoided-death benefit). Retirement at 75 is consistent with IGEM's construct of the available pool of quality-adjusted hours for work and leisure. It also appears reasonable insofar as less than three percent of 1990's civilian labor force was 65 and over with those 75 and over accounting for one third of these at most.

Table 4.1:
Year after which Persons No Longer
Appear in the CAA Mortality Benefit Stream

Age Category	Population Losses	Workday Losses
Infant	86	73
30-34	57	44
35-44	49	36
45-54	39	26
55-64	29	16
65-74	19	6
75-84	9	
85 and over	5	

An actuarial adjustment also was applied to EPA's workdays lost for reasons of illness or IQ loss. In the EPA data, morbidity-related workdays lost rise to over 2.0 percent of total workdays available by the early 2020's and continue to rise to just over 3.0 percent by century's end. A person's working life was assumed to be 47 years in the EPA analysis or, equivalently, ages 18 through 65. If the EPA series were adjusted in the manner above to account for normal retirements, then the workdays lost benefits peak at just over 2.0 percent in the early 2020's and gradually decline thereafter, falling to just under 1.0 percent by 2100. Since there are no age-cohort details available for the morbidity damages, a mid-point, terminal value of just over 2.0

percent of total workdays available was assumed. Essentially, the morbidity benefit trajectory tracks the EPA adjusted (and unadjusted) series to it peak of 2.0 percent where it remains for the balance of the simulation period.

It is useful to understand the composition of the morbidity damages. These initially are driven by chronic bronchitis arising from exposures to non-lead pollutants. In 1971, fifty percent of the unadjusted damages are due to chronic bronchitis. This proportion increases to 82 percent by 1980 and to 89 percent by 1990. It peaks at 93 percent in 1993 when the lagged effects of lead-related IQ point losses first appear. These, then, begin to exert more influence and, ultimately, dominate the morbidity damages. In the long run, chronic bronchitis accounts for 41 percent of the morbidity effects while the embodied productivity consequences of reduced IQ's among the workforce account for 56 percent of the effects; together, they comprise almost 97 percent of the non-expenditure morbidity benefit.

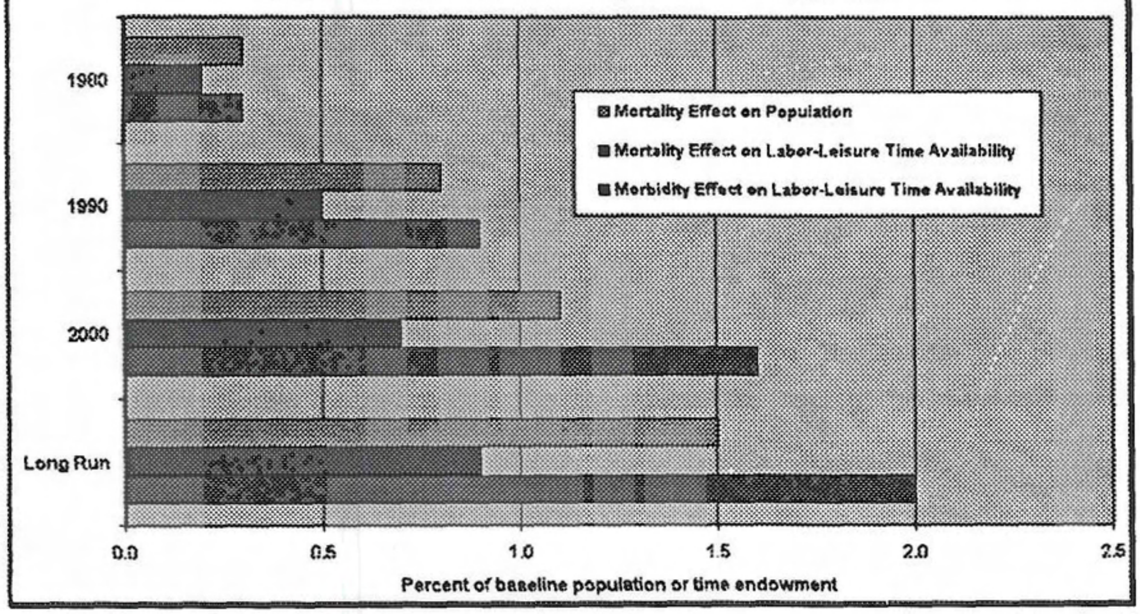
The direct benefits from the Clean Air Act are presented in Figures 4.1 and 4.2 below. Figure 4.1 summarizes the mortality and morbidity effects. Even in the near term, the estimated benefits from compliance with the Act are not trivial. By 1990, net avoided deaths are 0.8 percent of the population and, by 2100, they are 1.5 percent of the population. These deaths reduce labor availability by 0.5 and 0.9 percent, respectively. The morbidity effects add to these. By 1990, morbidity adds another 0.9 percent in activity days lost and, by 2100, morbidity accounts for an additional 2.0 percent reduction in labor's time endowment. The combined impacts on labor availability total 0.5 percent in 1980, 1.4 percent in 1990, 2.3 percent in 2000 and 2.9 percent by 2100.

The *1993 Statistical Abstract of the United States* (Table 126) reports death rates due to major cardiovascular diseases, chronic obstructive pulmonary diseases, pneumonia and influenza, and acute bronchitis of approximately 1.1 million persons in each of the years 1980 and 1990. The premature deaths (unrelated to lead exposure) underlying Figure 4.1 were estimated at 145,884 and 183,539 persons in 1980 and 1990, respectively. (These are 94 and 90 percent, respectively, of the total mortality effects.) These data imply that the Clean Air Act reduced the deaths due to the aforementioned illnesses by 12 and 15 percent in 1980 and 1990, respectively.

A similar perspective can be developed for the morbidity effects. By 1990, the morbidity effect has risen to almost 1 percent of the household time endowment. These damages are introduced as reductions in the discretionary, quality-adjusted time available (14 hours per day, 7 days per week and 52 weeks per year) for work and leisure. The morbidity benefits focus on avoiding restricted activity days and not simply avoiding work-loss days. While it turns out that the proportionate reductions in labor services (work) demanded and supplied mirror these damages, the labor-leisure decision is an internal model outcome. The *1993 Statistical Abstract of the United States* (Table 199) reports on disability days. In 1970, there were 2109 million restricted activity days associated with the 135.0 million non-school-aged persons under 65 years of age. In 1990, there were 2522 million restricted activity days associated with the 170.3 million non-school-aged persons under 65 years of age. This segment of the population, comprising around 90 percent of the working-age population, averaged 15.6 and 14.8 days of restricted activity per person in 1970 and 1990, respectively. On an annual basis, these figures indicate an activity loss (for both work and leisure) due to injury and illness of slightly more than 4 percent of all available days for almost 70 percent of the population. Moreover, this loss declined by over 5 percent between 1970 and 1990. In magnitude, EPA's morbidity benefits are in the range of 20 to 25 percent of these figures implying that the absence of the Clean Air Act would be responsible for an increase in excess of 20 percent in restricted activity days due to injury and illness. (Actual workdays lost averaging 5.4 and 5.3 days per civilian employee in 1970 and 1990, respectively, are only partially relevant here as the benefit focus is on the time available for work *and* leisure and the model ultimately determines the allocation of time to each.)

The expenditure effects portrayed in Figure 4.2 are relatively small, reaching a peak of less than 0.8 percent of all spending on personal and business services. Initially, the avoided expenditures rise in comparison to the underlying spending. However, by the early to middle 1990's, the pace of total spending on services begins to outstrip the estimated avoided expenditures on healthcare, home maintenance and education. For the period beyond 2000, it was assumed that avoided expenditures would remain at 0.7 percent of annual spending.

Figure 4.1: Mortality and Morbidity Effects
Counterfactual Scenario: No Adoption of the Clean Air Act



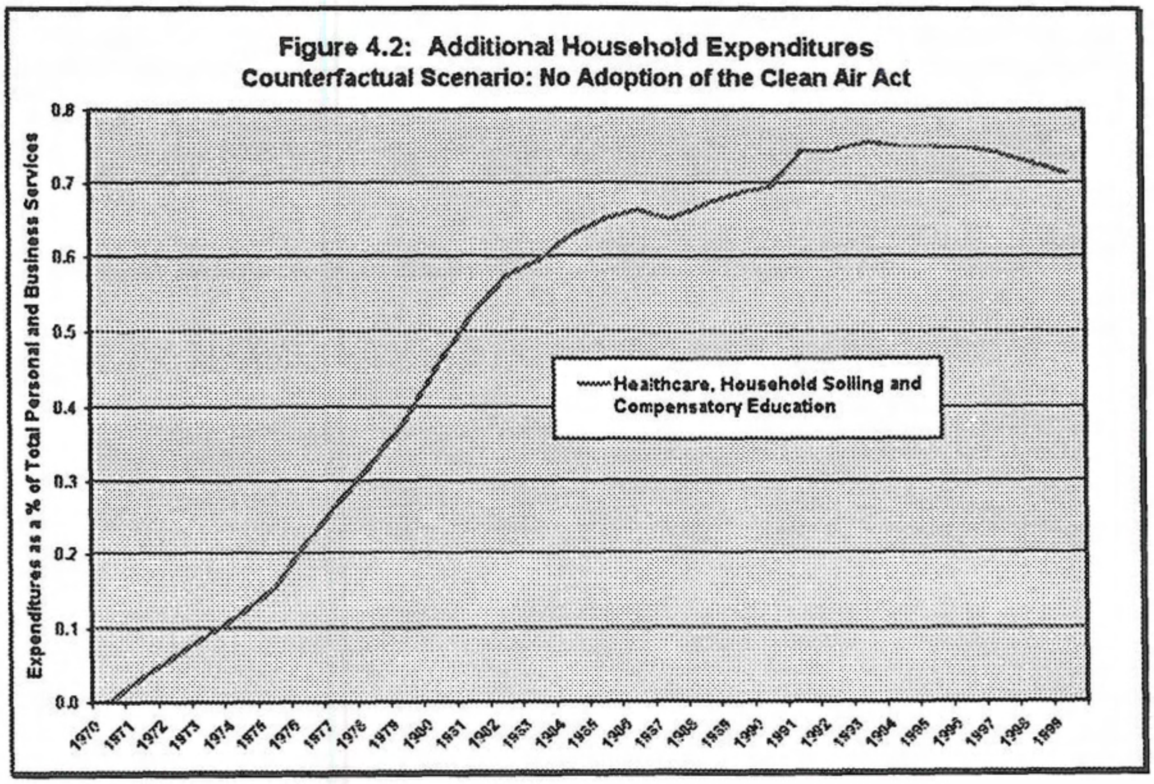


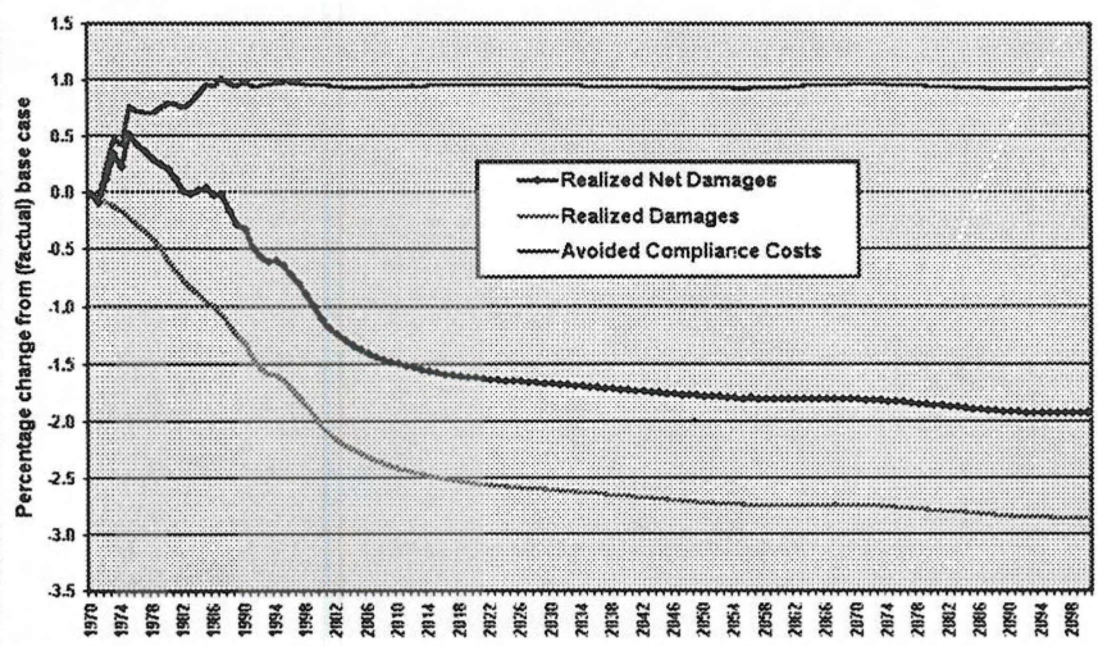
Figure 4.2: Additional Household Expenditures
Counterfactual Scenario: No Adoption of the Clean Air Act
Expenditures as a % of Total Personal and Business Services
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
Healthcare, Household Soiling and Compensatory Education

5. Economic Performance and Welfare

Economic Performance

The Clean Air Act provides sustained, long-run economic benefits. Real GDP ultimately is as much as 2.0 percent higher as a consequence of its enactment. Figure 5.1 summarizes these results. Note that in this figure and the ones to follow, economic costs appear as gains whiles economic benefits appear as losses; this is due to the counter-factual procedures adopted for the model simulations. Were the economy to avoid the costs of compliance, final spending eventually would be almost 1.0 percent greater. However, this ignores the benefits arising from the Act. Were these to be avoided, final spending eventually would be almost 3.0 percent lower. On balance, there are initial net economic losses as the private costs of compliance, operating through the "crowding out" of productive investment and through productivity decline, exceed the benefits of the avoided damages to life and health. By the late 1980's, there are annual net benefits as the ongoing avoidance of deaths and health-related workdays lost more than compensate the permanent costs of ongoing compliance. By the middle 1990's, there are cumulative net benefits that continue to grow as the time horizon is extended.

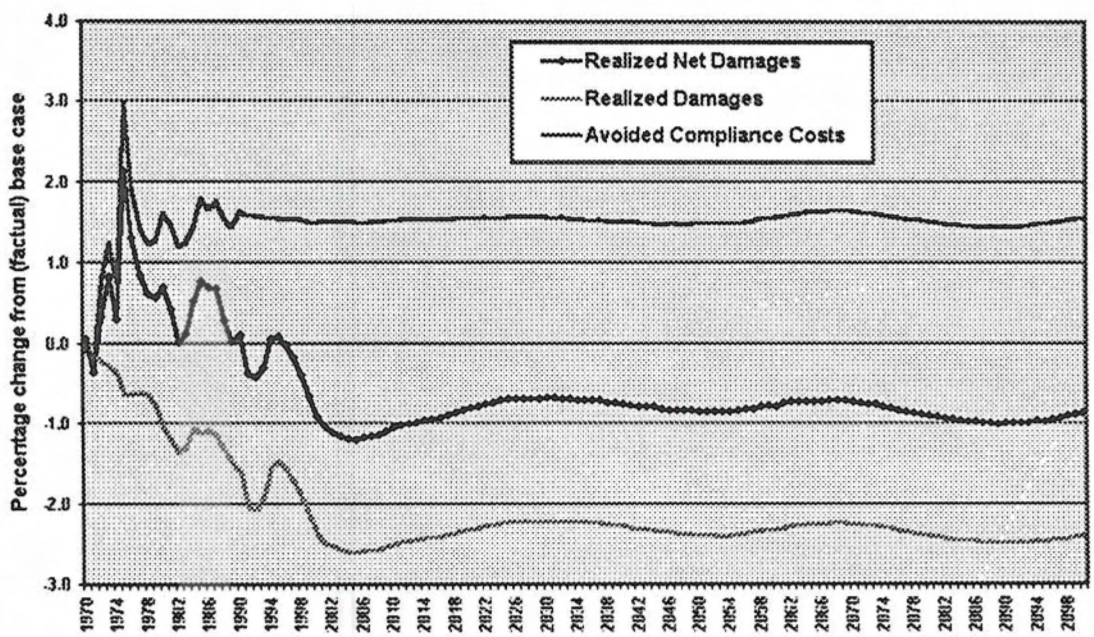
Figure 5.1: Impacts on Real GDP
Counterfactual Scenario: No Adoption of the Clean Air Act



The macroeconomic adjustments to CAA compliance are somewhat more intricate than the benefit adjustments. The principal impacts of compliance are on investment and capital accumulation and the economic restructuring associated with them. (See Figures 5.2 and 5.3.)

Adding a pollution control component to new capital is equivalent to raising the marginal price of investment goods. Combining this with the windfall loss of having to bring existing capital into compliance reduces the economy's rate of return on saving and investment. In turn, this reduces the level of real investment by producers and consumers. The price- and return-effects and less rapid (ordinary) capital accumulation imply a higher rental price for capital services and a corresponding lower demand. The capital rental price increases also serve to raise the prices of goods and services and, so, the overall price level.

Figure 5.2: Impacts on Real Investment
Counterfactual Scenario: No Adoption of the Clean Air Act



The price effects from investment changes are augmented by the cost increases associated with diverting resources to the operation and maintenance of pollution control equipment and by the higher prices caused by regulations on mobile sources. As a result of higher prices, each dollar flow supports fewer quantity purchases. Real consumption, real investment and real purchases by governments all fall. Ultimately, real income (Figure 5.1) and consumption (Figure 5.4) fall by one percent while real investment (Figure 5.2) and the capital stock (Figure 5.3) decrease by one and one half percent.

Figure 5.3: Impacts on Capital Stock
Counterfactual Scenario: No Adoption of the Clean Air Act

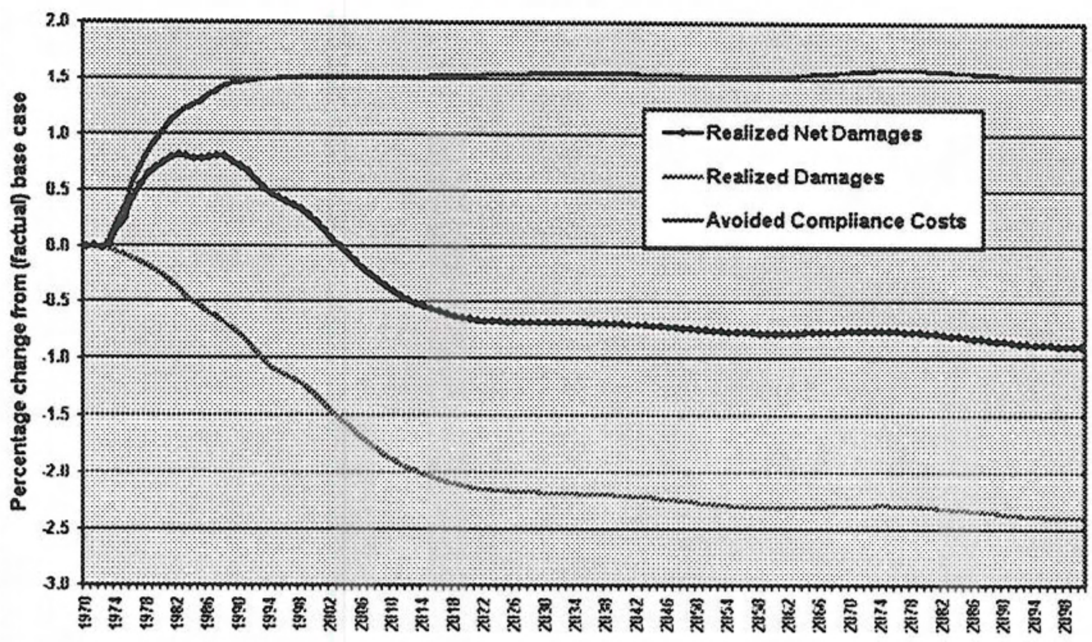
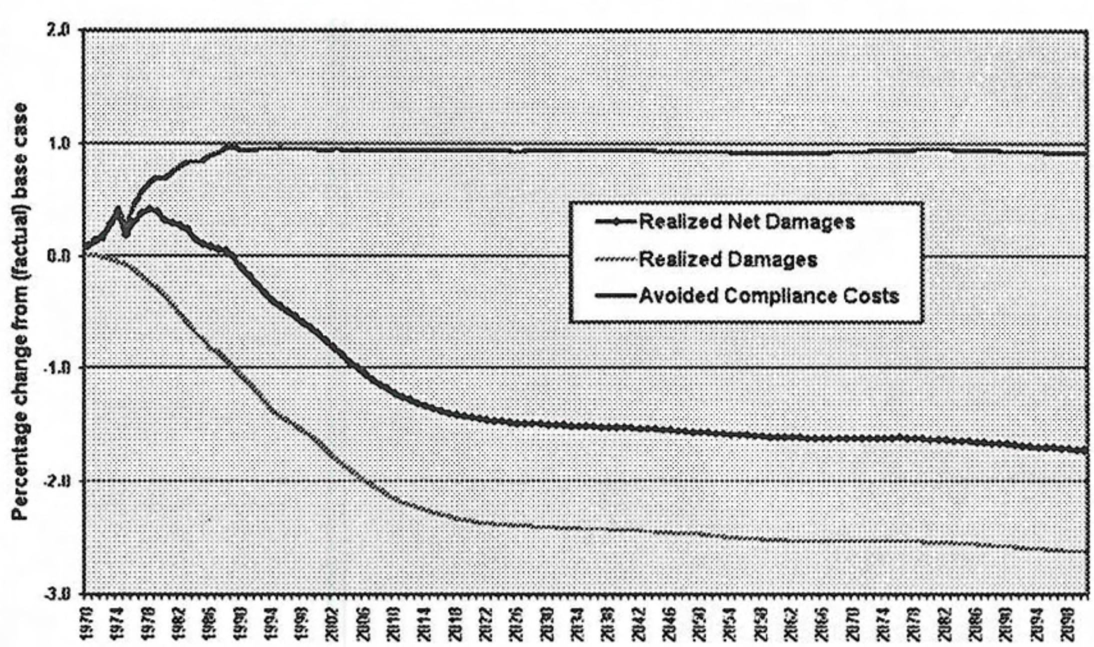
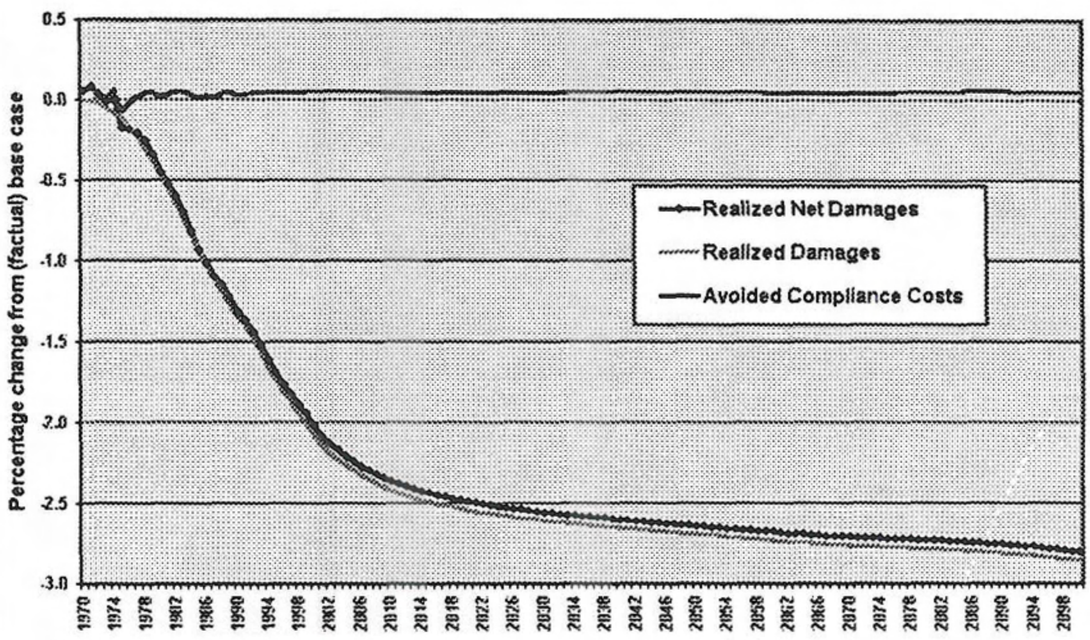


Figure 5.4: Impacts on Real Consumption
Counterfactual Scenario: No Adoption of the Clean Air Act



To households, CAA compliance costs act to reduce permanent future real earnings (income) through their price effects. This leads to a decrease in real consumption in all periods (Figure 5.4) and, generally, to decreases in household saving and the demand for leisure (Figure 5.5). Households marginally increase their offer of labor services (Figure 5.6) as the income effects of lower real earnings dominate the substitution effects of higher goods prices. The income effects arise as lower income leads to lower consumption of goods, services *and* leisure, thus increasing labor supply. The substitution effects arise as higher prices for goods and services promote less consumption of them and a greater consumption of leisure, thus reducing labor supply.

Figure 5.5: Impacts on Leisure Demand
Counterfactual Scenario: No Adoption of the Clean Air Act



Real spending by governments falls as a consequence of higher commodity prices and the adjustments that hold spending in line with changes in tax revenues and maintain (by assumption) government deficit at previous levels. Real net exports rise. This occurs as the dollar weakens by an amount that is sufficient to keep the current account surplus unchanged. Within this overall adjustment, real exports fall as the U.S. becomes less competitive. Real imports also fall because of the weaker dollar and, more importantly, because of the increases in motor vehicle and refined petroleum import prices that accompany CAA compliance.

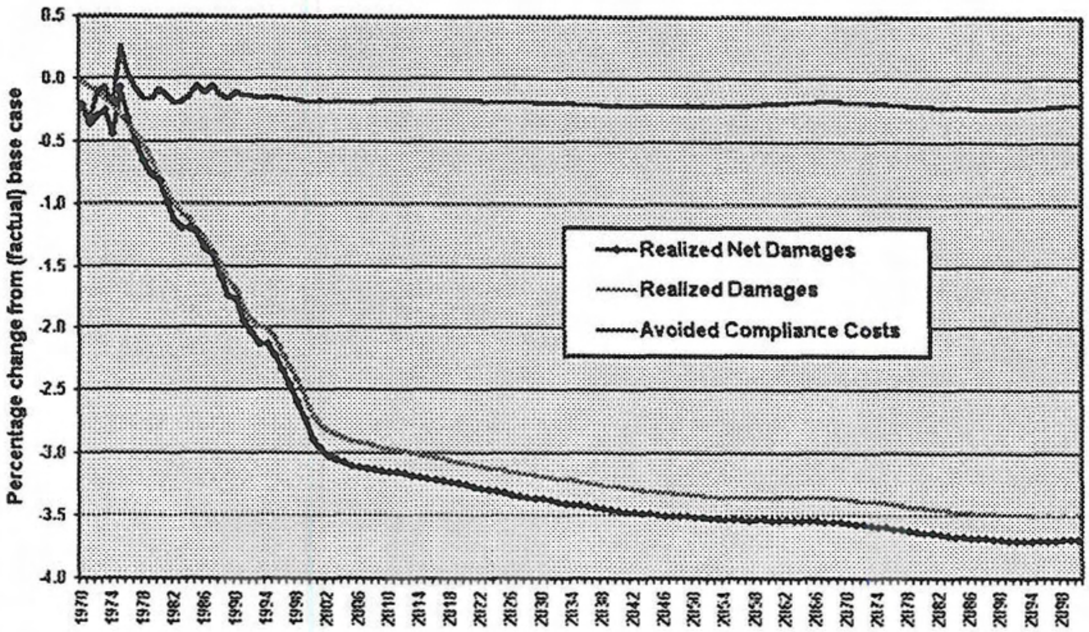
Finally, productivity effects offer additional supply-side costs to the economy. These arise mainly from the input and output restructuring that takes place. Relative price changes alter the input patterns within each producing sector and change the level of input-to-output productivity. Relative prices changes and the altered structure of final demand, both within and across spending categories, change the output composition of the economy. Since productivity differs among industries, this compositional change affects overall productivity. This output effect on overall productivity also appears in the input-to-output relation between the intermediate use of goods and services and final demand (value added). Lastly, there are smaller effects as higher factor prices decrease the endogenous rates of productivity growth in those industries that are factor using. Higher rental prices for capital harm the capital-using sectors, higher materials prices harm the materials-using sectors and higher energy prices harm the energy-using sectors. Thus, the principal effects arising from the costs associated with clean air initiatives are to slow the economy's rate of capital accumulation and, by restructuring economic activity, its overall rate of productivity growth.

The macroeconomic adjustments to CAA benefits are more straightforward. There is a small productivity benefit leading to lower prices as resources in the services sector are released from healthcare, home maintenance and compensatory education activities. There is a much larger benefit from having a larger population and time endowment. These affect the scale of the economy and the broad categories of spending within it. As shown in Figures 5.5 above and 5.6 below, the impacts on leisure demand and labor supply follow directly from the avoided deaths and workdays lost attributed to the Clean Air Act. These add primary inputs to production and consumers to purchase this output. Production and spending are simply greater, with increases approximately equal to the proportionate increases in people and time. More people and time favor labor supply and consumption proportionally more than saving and investment. For reasons of both demand-pull and cost-push, prices related solely to the benefits are higher under the CAA, the exception being services as noted above. Greater labor availability relative to capital encourages substitution of the former relative to the latter. Saving and investment and, hence, the nation's capital stock increase substantially but proportionally less so than labor supply and consumption. Labor and primary-factor productivity fall while capital productivity rises. The declining capital-labor ratio also contributes to slower overall productivity growth. Thus, the benefits of the Clean Air Act derive from its effects on the primary inputs to production, labor and, to a somewhat lesser extent, capital.

The net benefits of the CAA combine the early capital and productivity losses of compliance with the subsequent labor and capital gains associated with fewer deaths and workdays lost. In the short run, the Clean Air Act proves costly to the economy. A lower capital stock and reduced productivity more than offset the induced and benefit-driven gains from labor. However, over time, the benefits continue to mount while the compliance costs stabilize. Ultimately, under the CAA, the economy is larger with a larger population, a larger pool of labor and a greater capital stock.

It is interesting to note that much of the 1970's and 1980's were characterized by a relatively rapid growth in labor supply accompanied by comparatively slower rates of growth in capital accumulation and productivity. The 1990's experienced a significant reversal in the slowdowns in capital formation and productivity while continuing the strong trends in job growth. The nature and timing of the adjustments described above are entirely consistent with these observed patterns. Clearly, the Clean Air Act was not wholly responsible for the trends of the last thirty years. However, given the remarkable consistency of historic trends and the aforementioned adjustments, the Clean Air Act clearly exerted identifiably measurable influences on observed economic performance.

Figure 5.6: Impacts on Labor Demand & Supply
Counterfactual Scenario: No Adoption of the Clean Air Act



Welfare Considerations

The 1970 Clean Air Act and its 1977 Amendments secure a net benefit to economic welfare in the amount of $(1990) 26.2 trillion. A cumulative benefit of $(1990) 27.9 trillion is partially offset by market costs of $(1990) 1.7 trillion. The former arise as a consequence of the mortality, morbidity and productivity effects of the CAA while the latter reflect the direct and indirect costs of compliance. Table 5.1 summarizes the details of net welfare under the assumptions that benefits and costs accrue indefinitely and are discounted at IGEM's social rate of time preference of approximately 2.9%.

Table 5.1:
The Impacts on Household Welfare
Present Value to 1990 at 2.9%
Trillions of 1990 Dollars

Welfare Coverage	Net Benefit Calculation	Decomposition of Net Benefit Calculation
Total CAA Benefits	**$27.9**	
CAA mortality benefits based on the value of a statistical life (life-year) saved		$21.1

CAA morbidity and productivity benefits in terms of the market values of goods, services and leisure		+6.8
Less CAA costs in terms of the market values of goods, services and leisure	**-1.7**	-1.7
Equals CAA Net Benefits	**$26.2**	$26.2

Note: CAA mortality benefits in terms of the market values of goods, services and leisure are estimated at $(1990) 3.0 trillion.

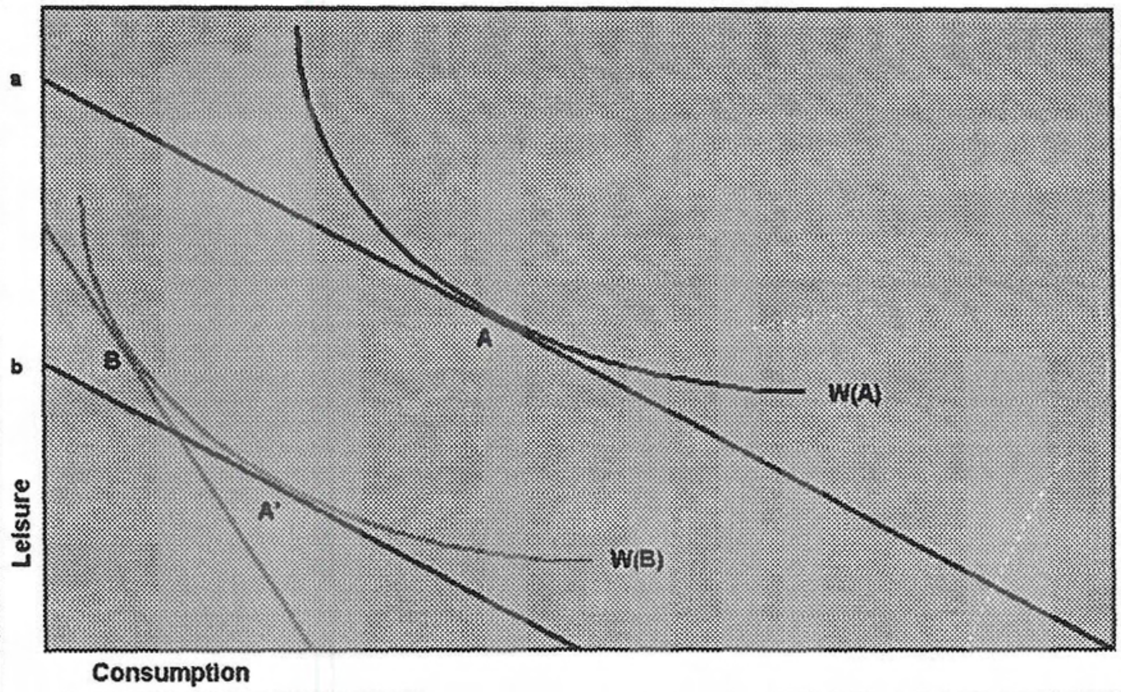
The mortality benefits of $(1990) 21.1 trillion combine EPA's value of a statistical life (VSL) saved with the cumulative, discounted population change attributable to the CAA. In assessing the mortality benefits of environmental policies, EPA employs a literature-based valuation for a statistical life saved of $(1990) 4.8 million (EPA 1997 and 2000). This figure goes beyond purely market considerations and measures the willingness-to-pay to avoid a premature death. As such, it incorporates not only a market-based willingness-to-pay in terms of foregone consumption and leisure but also an insurance or option premium willingly paid to avoid a foregone life. Valuations of a statistical life-year (VSLY) saved are easily determined from the lifetime value by computing annuities under various discount rates and time horizons. The $(1990) 21.1 trillion mortality benefit results from applying an annuity value of about $138,500 to the change in the discounted, present value population or, equivalently, from applying the 4.8 million to the discounted present value of the change in additions to the population. In the case of the former, an annuity value is used because benefits (i.e., particular avoided deaths) appear in multiple periods (i.e., until these same deaths would have occurred naturally). In the case of the latter, the lifetime valuation is used because benefits appear only once in the benefit stream (i.e., in the period in which the deaths were avoided).

IGEM offers a purely market view of economic welfare. Within IGEM, indirect utility functions are recoverable from the systems of household demand functions involving goods and services (i.e., consumption by commodity) and aggregate consumption and leisure (i.e., full consumption). These can be inverted to give the level of expenditure necessary to achieve a given level of welfare at a prevailing set of prices. From these, equivalent variations or households' willingness-to-pay are computed. These provide a broad market-based perspective of general equilibrium welfare in that all factor and product markets are considered on a national scale. However, this perspective is limited in that it does not consider welfare valuations beyond those reflected in market prices and transactions (e.g., the option value of an avoided premature death).

Although model structures differ greatly, the metrics in IGEM are conceptually identical to the work of Sieg, et. al. (2000) which estimates the welfare benefits of large scale reductions in ozone in Southern California taking into account the general equilibrium consequences for housing prices and location choice. (IGEM, of course, offers a broader notion of general equilibrium in that all factor and product markets are considered and in that its scale is national. However, the paths from theory to practice are the same.)

Figure 5.7 illustrates the market implications of a policy change for social welfare. (These features are illustrated for a static two-good world involving aggregate consumption and leisure. In IGEM, the actual welfare calculations are present value equivalent variations determined from the time paths of interest rates and the prices for goods, services and leisure.) Figure 5.7 involves a move from situation A to B in which there is a welfare loss from W(A) to W(B). Implicitly, there is an increase in the relative price of consumption and a general equilibrium reduction in national income. The loss in social expenditure (or, money metric loss) conditional on the prices and interest rates of situation A and the welfare level of situation B, denoted as {A', W(B)} is given by the vertical distance {b-a}. This represents the market compensation that is necessary to achieve the new welfare level at the original prices and is the social equivalent variation or the measure of society's willingness to pay.

Figure 5.7: Changes in Social Welfare



IGEM permits two aggregate views of household welfare. Each represents the present-value compensation that is necessary to achieve the welfare levels of a new situation at common base-case prices and interest rates; each is a present-value equivalent variation. The two measures differ in terms of what is included in the underlying welfare function. The broader measure covers full consumption or the aggregate of goods, services *and* leisure. The narrower measure covers consumption or the aggregate of goods and services alone. The former is more relevant to this analysis. This is because of its inclusion of leisure and the fact that the benefits of the CAA predominantly influence the availability of people and time.

In considering only the cost-side adjustments, CAA compliance leads to a market loss in social welfare of \$(1990) 1.7 trillion as shown in Table 5.1. This loss reflects the present-value changes in consumption and leisure that arise from the impacts on capital and productivity following enactment. It is this loss that partially offsets the \$(1990) 27.9 trillion gain, leaving a net welfare benefit of \$(1990) 26.2 trillion.

In considering the non-mortality benefits, the Clean Air Act secures a market gain in social welfare of $(1990) 6.8 trillion. This gain reflects the present-value changes in consumption and leisure that arise from the CAA-induced improvements in productivity and reductions in morbidity. The gains in productivity arise from reductions in environmentally related healthcare expenditures, household soiling costs that are no longer necessary and decreases in compensatory education expenditures associated with reduced lead concentrations. Adding this to the $(1990) 21.1 trillion in mortality benefits yields total CAA benefits of $(1990) 27.9 trillion.

Finally, and only for completeness, the mortality benefits of the CAA in terms of market gains in consumption and leisure are estimated at $(1990) 3.0 trillion. This measure is not employed in computing the social benefits of the CAA because it fails to reflect an all-important determinant of mortality valuation, namely, the insurance premium or option value willingly paid to avoid premature death. Instead, it is presumed to be part of the $(1990) 21.1 trillion in total CAA mortality benefits.

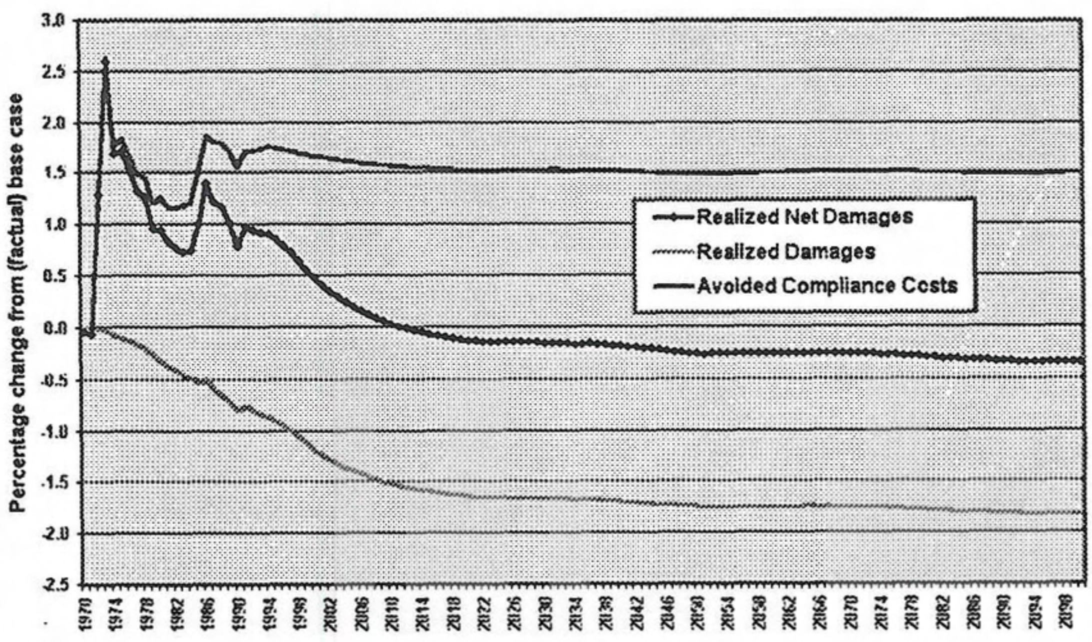
A perspective on IGEM's market valuation of mortality lies in the foundations of EPA's estimate of the value of a statistical life (VSL) saved. In the literature survey underlying EPA's $(1990) 4.8 million mean value, the range of valuations is from $(1990) 600,000 to 13.5 million or from 13 to 181% of the mean amount. The standard deviation from this range of observations is $(1990) 3.2 million or 67% of the mean amount. In addition, sensitivity analyses conducted by EPA on mortality benefits find the 5th percentile estimates to lie in the range of 15 to 25% of the mean and the 95th percentile estimates to lie in the range of 120 to 150% of the mean. The $(1990) 3.0 trillion market value of benefits from IGEM corresponds to a VSL of about $(1990) 700,000. This is toward the low end of EPA's range of data and analyses which is not surprising since it is based solely on market considerations. Were the CAA benefits to comprise only the market valuations from IGEM, a total market-based benefit of $(1990) 9.8 trillion also would more than compensate the $1.7 trillion cost, leaving a net welfare gain of $(1990) 8.1 trillion in terms of additional consumption and leisure. This is consistent in sign and magnitude with the economic findings discussed above. Still, it is not an appropriate welfare valuation because it does not fully capture the considerations of willingness-to-pay that are common in the VSL and mortality-benefit literature. On balance, the conclusion that the insurance premium or option value on a statistical life adds significantly to the net welfare gain in purely market terms seems well justified and, therefore, the net welfare gain of $(1990) 26.2 trillion for the CAA appears quite defensible.

The welfare results become more readily identifiable when expressed on an annual basis. At IGEM's social rate of time preference of 2.9%, the CAA net benefit of $(1990) 26.2 trillion corresponds to a benefit of $(1990) 756 billion annually. Real GDP in the year 2000 was about $(1990) 7,980 billion. In percentage terms, the CAA net benefit represents less than ten percent of current income. As significant as this seems, the benefits are far smaller proportions of overall economic activity than some have portrayed them (e.g., Sieg, et. al., 2000). Moreover, these results reflect the magnitudes of the avoided premature deaths and adverse health consequences attributed to the CAA. As described in Section 4, the CAA is estimated to save lives in the range of 15.0 percent of those dying from cardiac and respiratory/pulmonary diseases and to reduce restricted activity days in excess of 20.0 percent leaving more time for work and leisure. Accordingly, in the long run, the absence of the CAA leads to a population that is 1.5 percent smaller and to a time endowment of labor that is almost three percent smaller. Thus, the magnitudes of net welfare benefits cannot be considered too surprising in view of the direct environmental consequences upon which they are based.

6. Energy and the Environment

IGEM features two physical indicators for energy and the environment that are driven by economic variables within its structure. These are aggregate fossil fuel use and carbon emissions. Figures 6.1 and 6.2 show the effects on these for the cost, benefit and combined benefit-cost simulations. The Clean Air Act secures substantial reductions in fossil fuel use and carbon emissions through the early years of the 21st century. Isolating the costs, energy reductions follow from the patterns of energy price increases and stabilize at 1.5 percent of base use. Emissions reductions follow a similar pattern but are slightly smaller in magnitude. Isolating the benefits, energy use and emissions increase gradually reflecting the increasingly larger economy. By 2010 or so, both fossil fuel use and carbon emissions are slightly higher than they would be in absence of the Clean Air Act. The long-run increases are in the range of 0.5 percent of base levels.

Figure 6.1: Impacts on Fossil Fuel Use
Counterfactual Scenario: No Adoption of the Clean Air Act



Figures 6.3 and 6.4 show, respectively, the relations of fossil fuel use and carbon emissions changes to changes in real GDP for the combined benefit-cost simulation. It is clear that the Clean Air Act secures permanent and significant reductions in the energy- and emissions-intensities of economy activity. However, as shown in Figure 6.5, the emissions-intensity of fossil fuel use increases under the act. As will be discussed in Section 7, this arises because of the reduced petroleum-intensity and increased coal-intensity of the nation's energy-consuming capital stock.

Figure 6.2: Impacts on Carbon Emissions
Counterfactual Scenario: No Adoption of the Clean Air Act

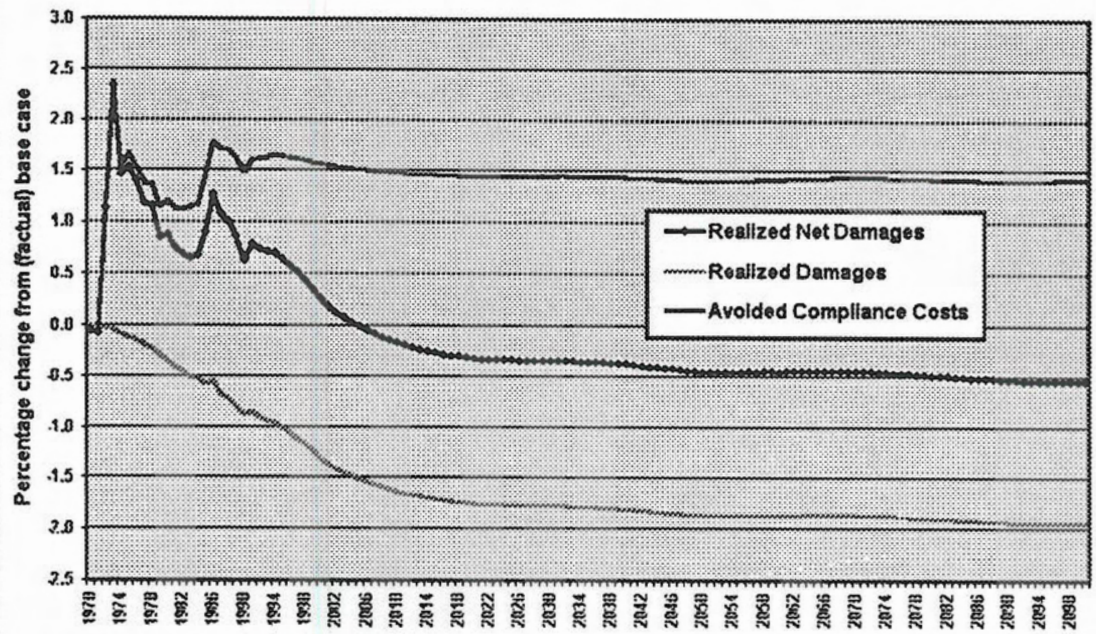


Figure 6.3: Net Impacts on the Fossil Fuel Intensity of the Economy
Counterfactual Scenario: No Adoption of the Clean Air Act

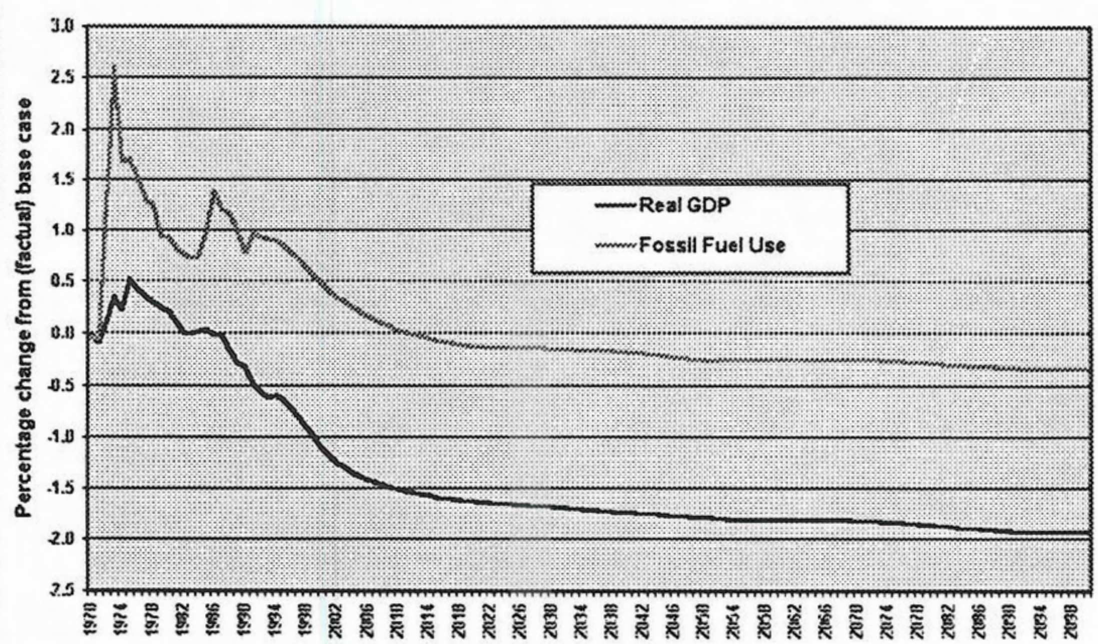


Figure 6.4: Net Impacts on the Carbon Intensity of the Economy
Counterfactual Scenario: No Adoption of the Clean Air Act

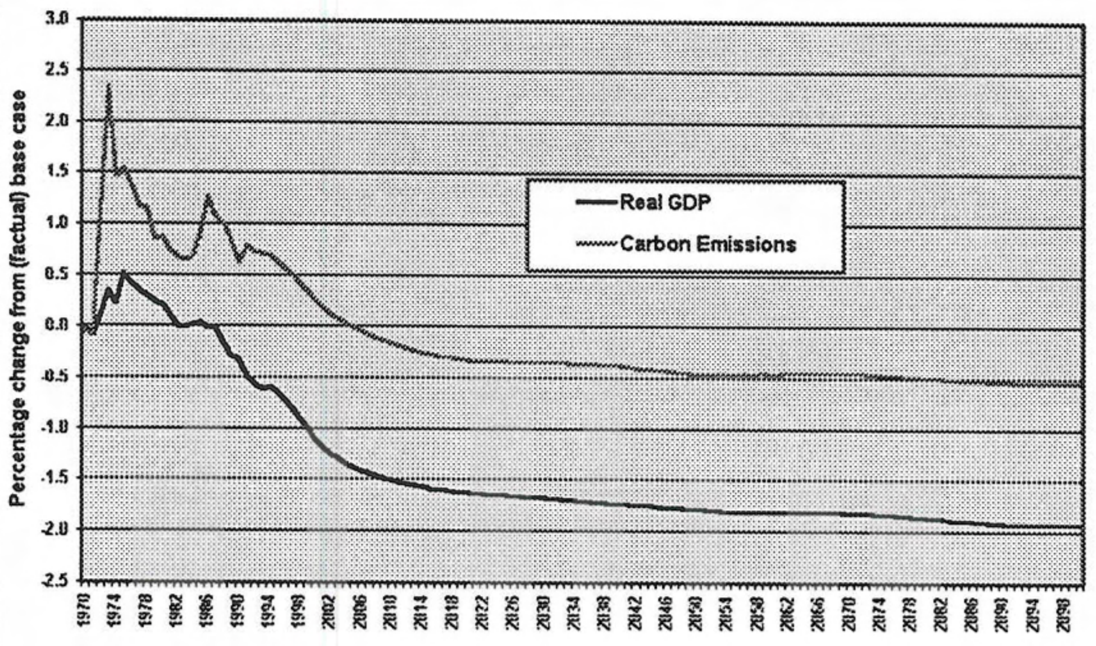
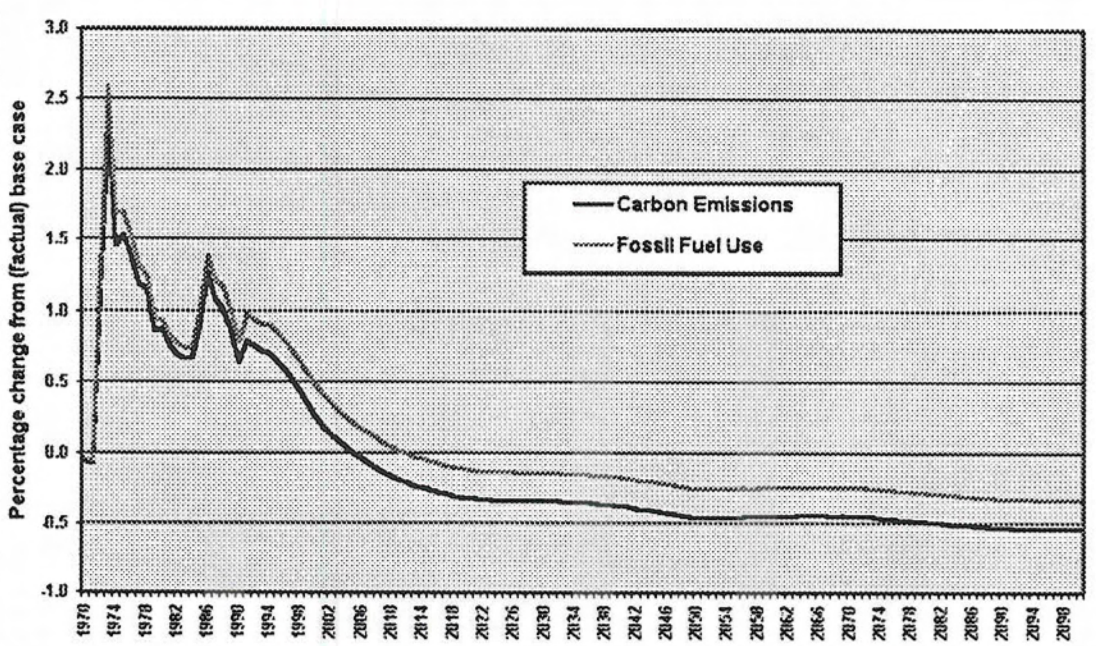


Figure 6.5: Net Impacts on the Carbon Intensity of Fossil Fuel Use
Counterfactual Scenario: No Adoption of the Clean Air Act



7. The Structure of Economic Activity

The Clean Air Act has its biggest direct impacts on the petroleum refining, motor vehicle and electric utility sectors (see Tables 3.1 and 3.3). To lesser extents, metal and coal mining, chemicals, primary metals and gas utilities also are affected directly. Operating through influences on price and productivity, these impacts are illustrated in Figure 7.1. This shows industry supply prices for 1990 as compliance costs were counter-factually eliminated. Figure 7.2 shows the output consequences of cost-side adjustments. Clearly, the CAA costs affect the composition of domestic supply. The mechanisms are as follows. Relative price changes follow from the CAA cost impacts and, in turn, alter the input patterns within each producing sector (compare Figures 3.2 and 7.1). For example, the direct effects in 1990 on the prices of refined petroleum, motor vehicles and electricity utilities are in the range of 1.5 to 2.5 percent and account for a majority of the general equilibrium price effects observed in Figure 7.1. These changes combine with the altered structure of final spending, both within and across the categories of final demand (consumption, investment, government and net foreign purchases), to change the output composition of the economy (see Section 4). As expected, those commodities whose cost structures are most affected by the CAA experience the largest comparative decreases in demand and supply under the Act. These include chemical and petroleum products, motor vehicles and other transportation equipment, and electricity and gas supply. Indirectly, these decreases and the decreased relative importance of investment goods adversely affect mining (energy and non-energy alike), the metals industries, and transportation services.

There are a few sectors that comparatively expand upon introduction of the CAA compliance costs. These include food and tobacco, furniture and fixtures, rubber and plastics, electronic equipment and high technology instruments, and services. For services, the expansive indirect effects of economic restructuring complement the benefits arising from reduced vehicle maintenance costs. In broad terms, compliance with the CAA appears partly responsible for accelerating the transition of the U.S. industrial landscape - a transition that is marked by the declining relative importance of basic industries and the increasing relative importance of technology and services.

The patterns of price and output changes associated with the Clean Air Act's benefits are much more uniform in nature. (See Figures 7.3 and 7.4.) The lone exception to this is the services sector that, here, reflects the productivity consequences of additional spending on healthcare, home maintenance and compensatory education. Beyond this, industry price and output changes are similar in magnitude and identical in direction. These mainly reflect the scale of activity, the economy being over one percent larger, and broad compositional changes as in proportionally greater increases in investment than in consumption.

Combining the benefits and costs of the Clean Air Act as in Figures 7.5 through 7.8 makes the mix of industrial winners and losers all the more visible. Figures 7.5 and 7.6 show the dynamic impacts on selected industries from the combined effects of CAA costs and benefits while Figures 7.7 and 7.8 are as above. In the presence of this legislation, the economy is larger but is much less intensive in mining, crude oil and gas extraction, petroleum refining, primary metals and motor vehicle production, and electric generation. However, electric generation is more coal- and gas-intensive and less oil intensive, which accounts for the increasing (carbon) emissions-intensity of fossil fuel use. Finally, the economy is much more intensive in the production of consumer non-durable goods, high technology capital equipment and services, the latter being aided by reduced housing and vehicle maintenance costs and avoided healthcare and educational expenses.

Figure 7.1: Impacts on Domestic Supply Prices, 1990
Counterfactual Scenario: No Adoption of the Clean Air Act

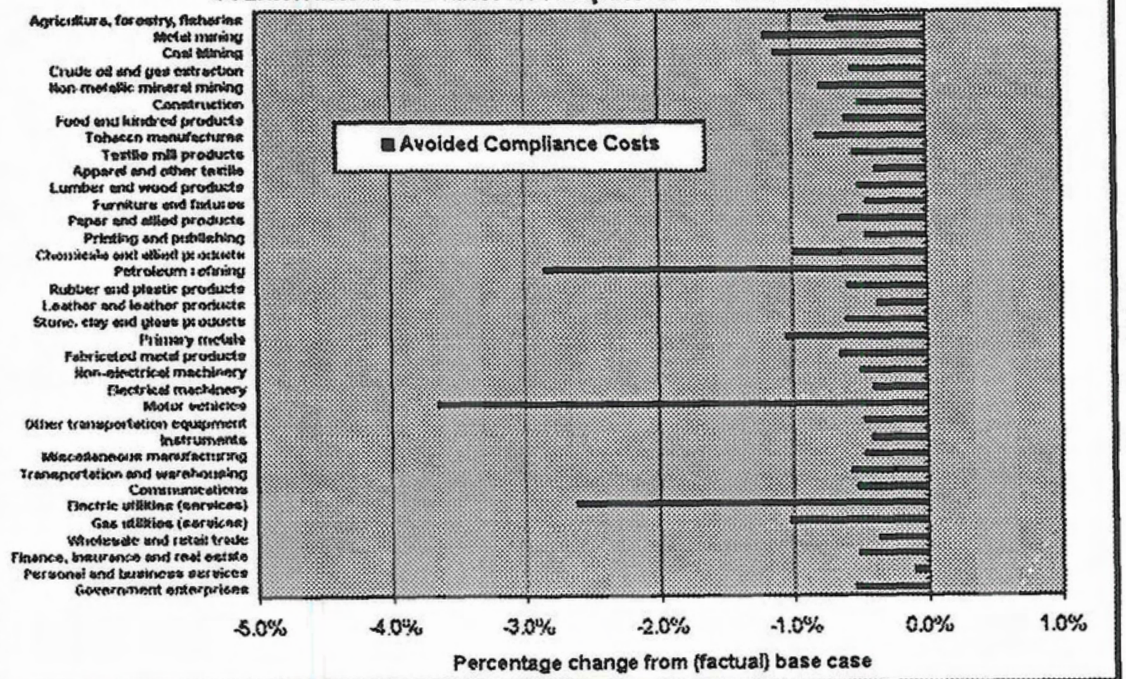


Figure 7.2: Impacts on Domestic Output, 1990
Counterfactual Scenario: No Adoption of the Clean Air Act

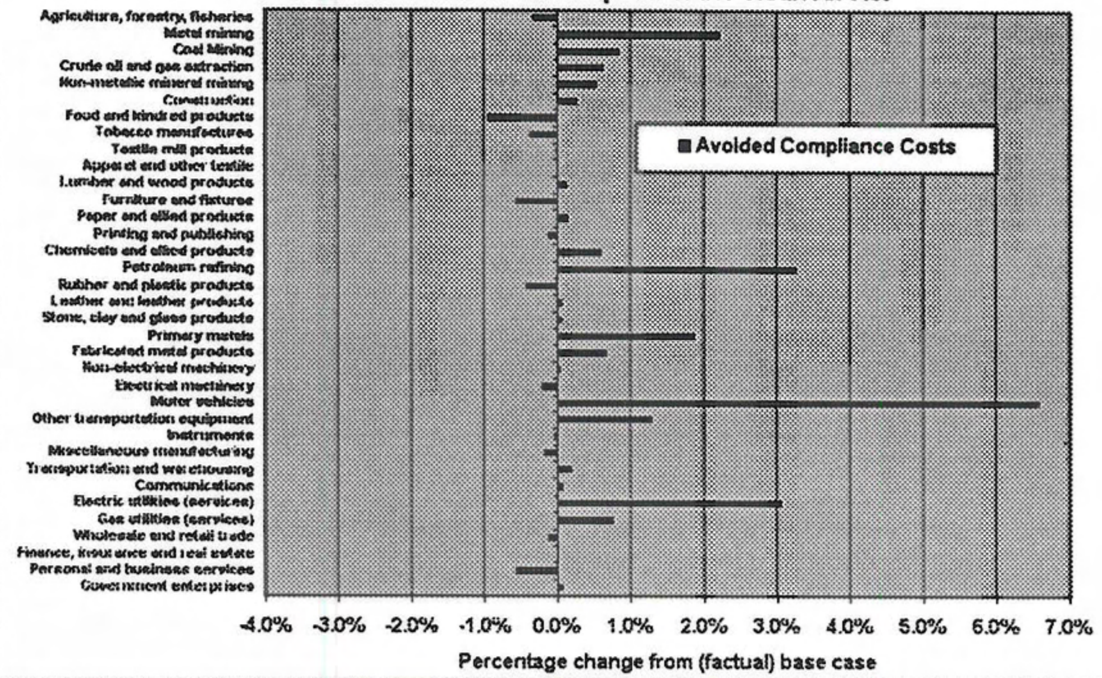


Figure 7.3: Impacts on Domestic Supply Prices, 1990
Counterfactual Scenario: No Adoption of the Clean Air Act

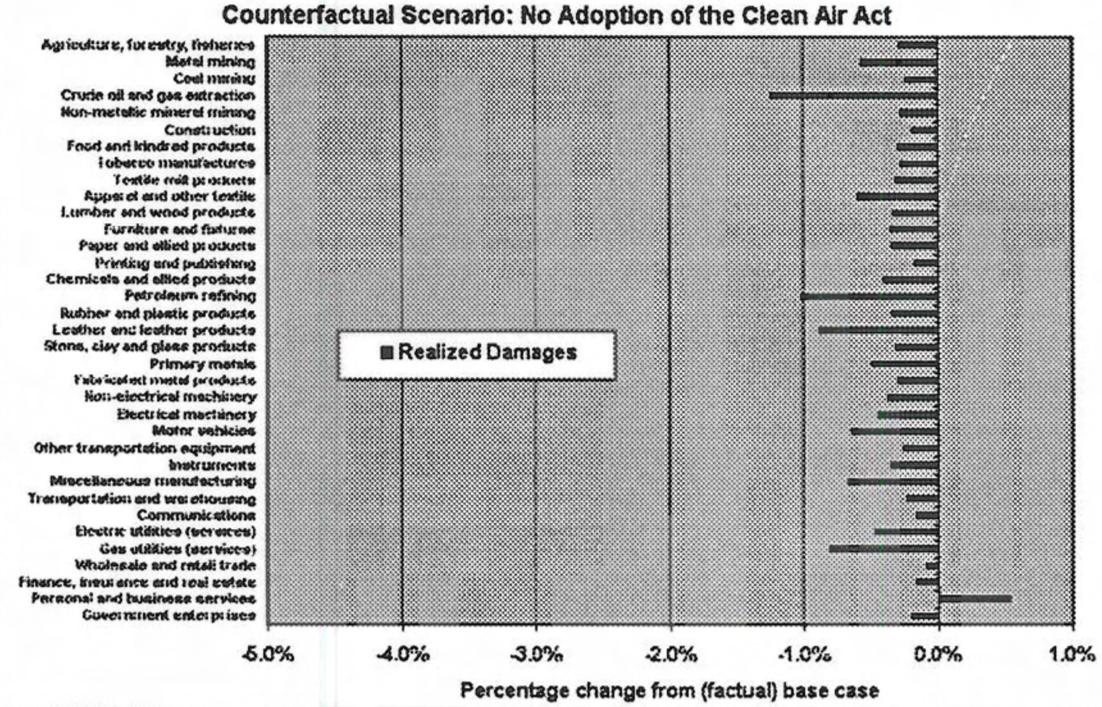


Figure 7.4: Impacts on Domestic Output, 1990
Counterfactual Scenario: No Adoption of the Clean Air Act

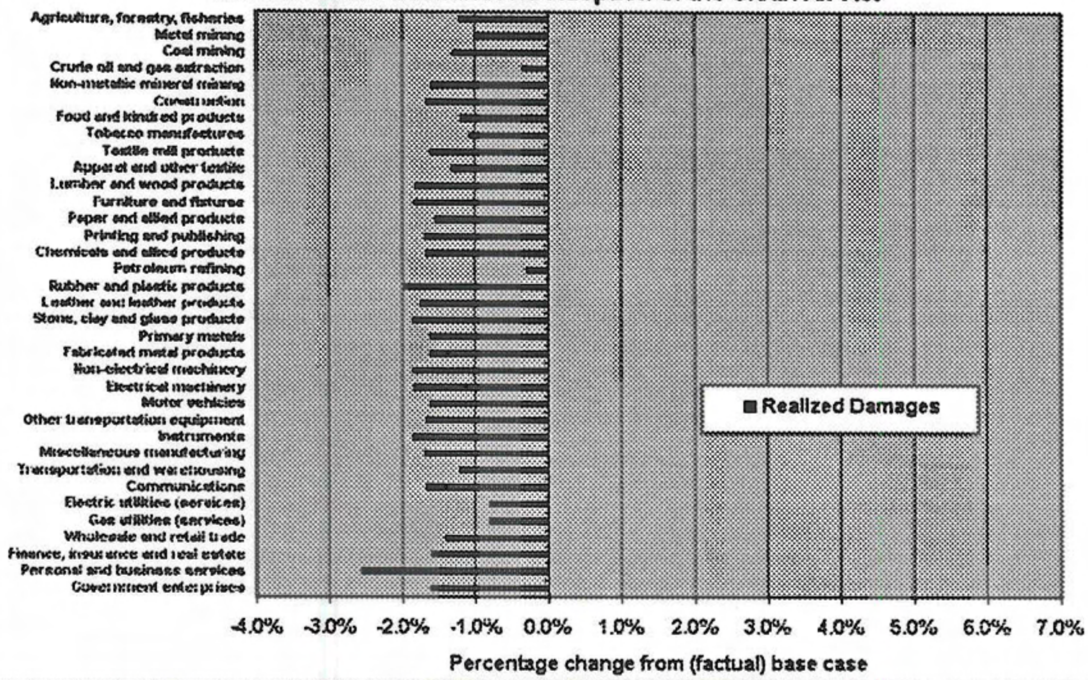


Figure 7.5: Realized Net Impacts on Domestic Supply Prices
Counterfactual Scenario: No Adoption of the Clean Air Act

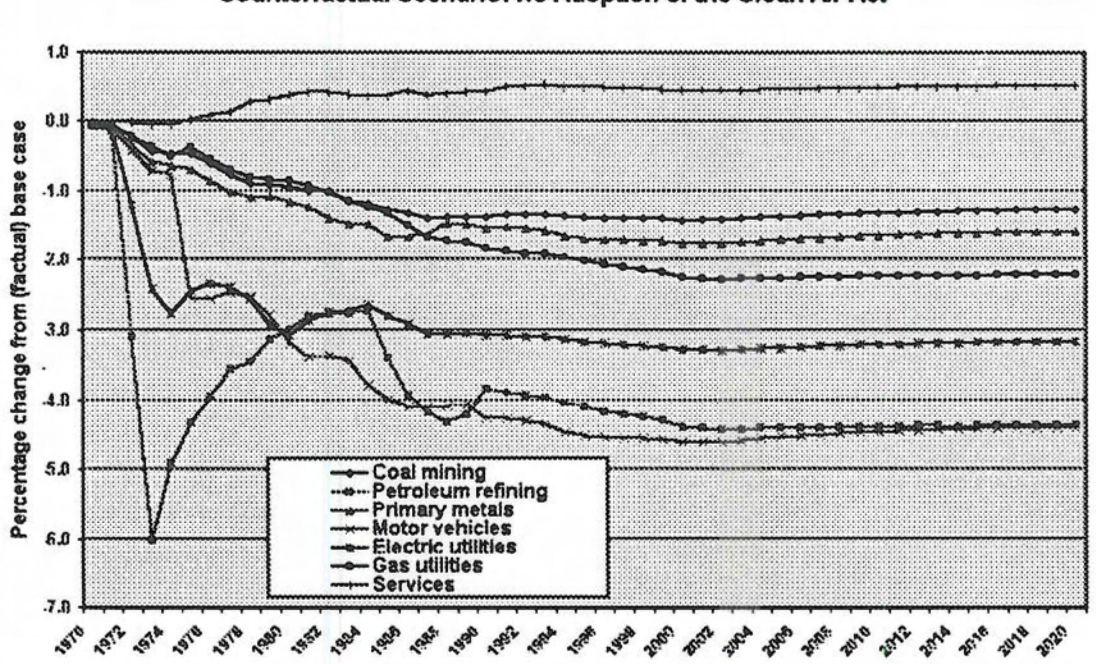


Figure 7.6: Realized Net Impacts on Domestic Output
Counterfactual Scenario: No Adoption of the Clean Air Act

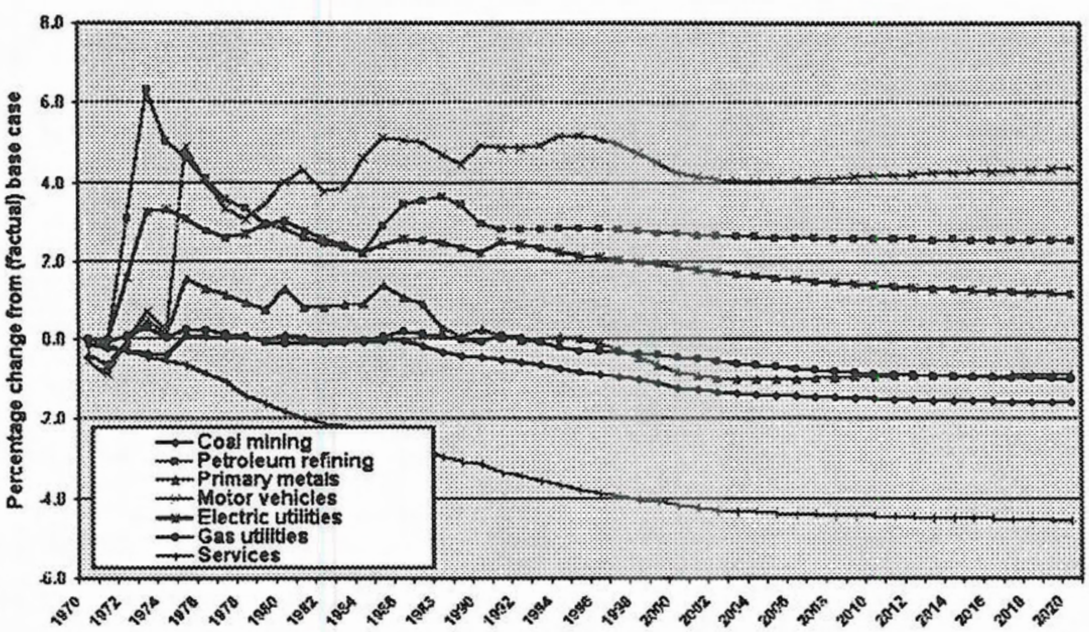


Figure 7.7: Impacts on Domestic Supply Prices, 1990
Counterfactual Scenario: No Adoption of the Clean Air Act

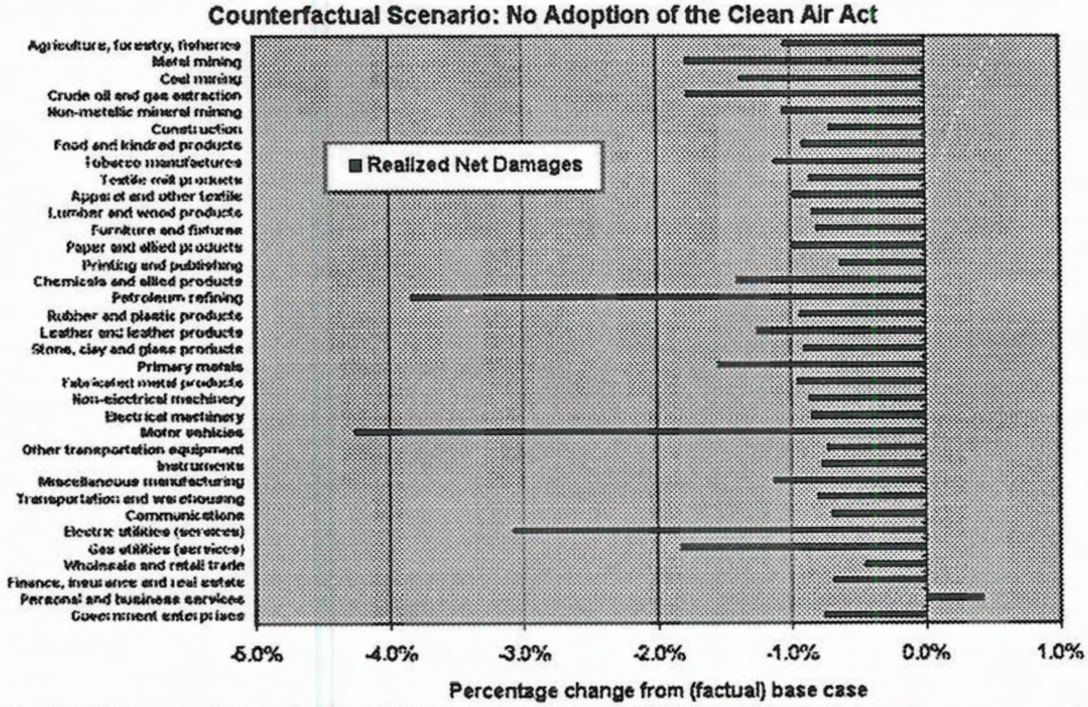
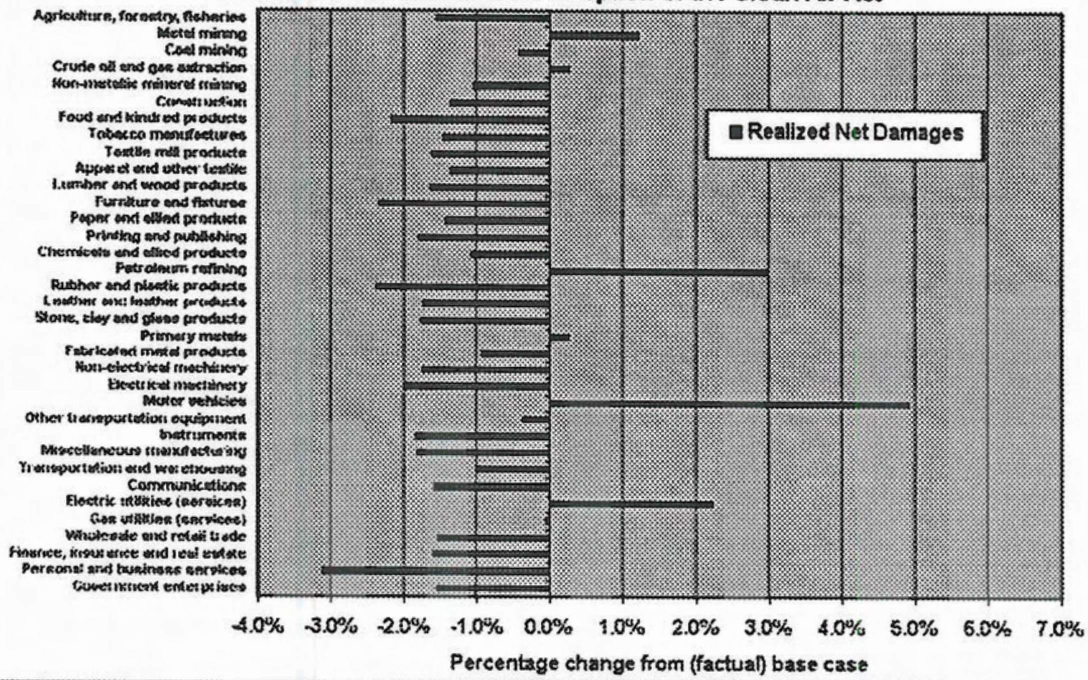


Figure 7.8: Impacts on Domestic Output, 1990
Counterfactual Scenario: No Adoption of the Clean Air Act



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